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ABSTRACT

This report extensively reviews the progress of the United States in space during 1967, the tenth year of the space age. The first chapter of the report summarizes the 1967 space activities; and each of the remaining 13 chapters is devoted to reviewing the space-related activities of a particular federal agency (13 agencies included). Appendices provide various information on the United States and Soviet space records, including a listing of successful launchings during 1967, major space firsts of the United States and the Soviet Union, American launch vehicles, historical summary of the space activities budget, and other information. (PR)

REPORT TO THE CONGRESS

FROM THE PRESIDENT OF THE UNITED STATES

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UNITED STATES AERONAUTICS AND SPACE ACTIVITIES

1967

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REPORT TO THE CONGRESS

FROM THE PRESIDENT
OF THE UNITED STATES

E PLURIBUS UNUM

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL AERONAUTICS AND SPACE COUNCIL
WASHINGTON, D. C. 20502

PRESIDENT'S MESSAGE OF TRANSMITTAL

TO THE CONGRESS OF THE UNITED STATES:

This report details a year -- and climaxes a decade -- of American progress in space.

On January 31, 1958, a 31-pound EXPLORER I was fired from a JUPITER C rocket with 150,000 pounds of thrust. Ten years later, on November 9, 1967, a 280,000-pound APOLLO payload was launched into orbit by a SATURN V rocket with 7.5 million pounds of thrust.

In the time spanning those two events, the United States has placed 514 spacecraft in earth orbit. Twenty-eight others have been sent on flights to the moon or distant planets.

The technology amassed through those expeditions has justified this nation's commitment to conquer the challenge of space. It has encouraged us to lift our eyes beyond our initial goals and plan for the decade ahead.

The fruits of that technology have not been limited to space exploration alone. The knowledge built through our space program has benefited our earthbound lives. It has:

-- revolutionized communications throughout the world;

-- given us better weather information and more accurate navigational and geographic data;

-- brought improved medical instruments and techniques, advanced education, and added to our store of scientific knowledge;

-- spurred the development of more sophisticated aircraft and improved flight safety;

-- strengthened both the security of this nation and our leadership in the search for a peaceful and secure world.

We can look with confidence to an expansion of these benefits as our space program moves into its second decade.

Our accomplishments thus far point to the path of progress ahead: fuller observations of the earth, increasingly productive manned flights, and planetary exploration.

The year 1967 itself began with a major tragedy. Three of our gallant astronauts died in a fire while testing the APOLLO capsule on the launching pad. Even as we saluted these men for the contributions they had made, we moved to improve the spacecraft as well as the safety procedures surrounding its use.

But though the year was shadowed by that disaster, its accomplishments significantly advanced our progress. The SATURN-APOLLO flight in November was the greatest launch triumph to date. As the result of our success in photographing lunar landing sites, we have for the first time a complete mapping of the moon.

It is most heartening to me that our space program moved forward in a spirit of international cooperation, giving new hope that the conquest of space can contribute to the establishment of peace. Eighty-four nations participated in cooperative space activities with us. The Outer Space Treaty went into effect, after Senate approval. The United Nations unanimously recommended a procedure for the emergency rescue and return of astronauts and space equipment. I shall shortly be sending that treaty to the Senate.

It is with pleasure that I transmit this record of achievement to the Members of Congress, whose judgment and support have been essential to our aerospace progress.

THE WHITE HOUSE
January 1968

Lyndon B. Johnson

TABLE OF CONTENTS

Chapter I U. S. Aeronautics and Space Activities--1967 Summary 1
Chapter II National Aeronautics and Space Council 6
Chapter III National Aeronautics and Space Administration . . . 10
Chapter IV Department of Defense. 44
Chapter V Atomic Energy Commission. 63
Chapter VI Department of State 69
Chapter VII National Science Foundation. 72
Chapter VIII Department of Commerce 77
Chapter IX National Academy of Sciences - National Academy of Engineering - National Research Council . . . 91
Chapter X Smithsonian Astrophysical Observatory. 99
Chapter XI Department of Transportation. 104
Chapter XII Federal Communications Commission 112
Chapter XIII United States Information Agency 115
Chapter XIV Arms Control and Disarmament Agency 121

Appendix A-1 U. S. Spacecraft Record (Chart) 123
Appendix A-2 U. S. Spacecraft Record (Table) 124
Soviet Spacecraft Successfully Launched 124
Appendix A-3 Successful U. S. Launches - 1967 125
Appendix B Ten-Year Listing of Major Space "Firsts" Achieved by the U. S. and the USSR 132
Appendix C Historical Summary - U. S. Unmanned Lunar and Planetary Probes 134
Appendix D U. S. Space Launch Vehicles 136
Appendix E Radioisotopic Power Systems for Space Applications. 137
Appendix F-1 Historical Summary and FY 1969 Budget Recommendations (New Obligational Authority) . 138
Appendix F-2 Historical Summary and FY 1969 Budget Recommendations (Expenditures). 139
Appendix F-3 Space Activities Budget; Aeronautics Activities Budget. 140
Index 141

CHAPTER I

U. S. AERONAUTICS AND SPACE ACTIVITIES *1967*

SUMMARY

In the tenth year of the Space Age, the national space program of the United States experienced its first major tragedy--and achieved its greatest launch triumph to date. The Nation advanced its technology to new heights, making vital progress in the drive to land men on the Moon in this decade and also to applying space-generated competence toward improving the lot of mankind.

As the year moved along the national space program faced increasingly serious funding competition from other high-priority programs. There continues, however, strong support for the program's objectives and policy.

A tragic fire on January 27 in an APOLLO spacecraft at Cape Kennedy took the lives of three astronauts. After an intensive investigation, NASA undertook to make changes in the spacecraft itself, in operating procedures, and in organization. Schedule delays and cost increases have resulted but risks have been decreased and equipment improved.

On November 9, a SATURN V vehicle was launched for the first time, carrying an unmanned APOLLO spacecraft into orbit. The spacecraft was carried to an altitude of 11,252 miles, from which it successfully re-entered the Earth's atmosphere at a velocity equivalent to that of a re-entry on return from lunar flight. The SATURN V vehicle performed magnificently, using the unprecedented 7,500,000 pounds of thrust in its first stage to boost a record 278,699-pound payload into orbit. This was a heartening demonstration of the ever-growing capabilities of the U. S. program. Six more SATURN-APOLLO flights are planned for 1968, and five in 1969. One of the latter may be our first manned Moon landing mission.

Largely in preparation for our manned lunar landings, NASA carried its LUNAR ORBITER series to successful completion during the year, concluding photographic surveys of eight proposed lunar manned landing sites. The program, with five successes in five attempts during 1966 and 1967, furnished photographs of the entire surface of the Moon in detail 100 times greater than could be provided by Earth-bound telescopes. It also sent back the first photographs of Earth taken from lunar orbit.

Three soft-landing SURVEYOR spacecraft supplied more than 50,000 close-up photographs of the Moon. In addition, they dug out a small trench, made chemical analyses of the lunar soil, and one even fired its vernier engines to lift the spacecraft 10 feet above the surface and re-land it 8 feet away. Results of the program indicate that the Moon's surface will adequately support manned landing craft. Two SURVEYORS were still operating as the year ended, and the seventh and last in the series is scheduled for launch in early 1968.

Far beyond the Moon, the year saw a major interplanetary success when the MARINER V spacecraft, launched June 14, flew-by within 2,600 miles of Venus on October 19. The Soviet Union's VENERA 4 spacecraft, launched on June 12, had soft-landed on the planet on October 18. The two spacecraft made complementary measurements of the environment, vastly increasing our understanding of this neighboring planet.

Within the Earth's atmosphere, there were major developments during the year in aeronautics. Here, too, tragedy struck, as an X-15 pilot was killed when his aircraft disintegrated in flight over the Mojave Desert on November 15. This was the first flight fatality in the history of the eight-year-old program. During the year the program investigated manned maneuverable travel at hypersonic speeds, and on one flight a new speed record of 4,534 miles per hour was set.

Elsewhere in the field of aeronautics, the Supersonic Transport (SST) program moved into its prototype development phase. On May 1, two days after the President announced the decision to proceed with the program, the Federal Aviation Administration signed contracts with the two industry companies which had won design competitions for the SST airframe and engines, respectively. The first prototype SST is scheduled to fly in 1970, and production planes are expected to go into commercial service by about 1974.

On the military side of aviation, the manufacture and assembly of the world's largest aircraft, the C5A transport, continued on schedule. Roll-out of the first craft is scheduled for February, 1968, and first flight is expected in June, 1968. The first F-111A with operational capability was delivered on October 16.

An advance with significance for both aeronautics and astronautics was a successful series of Air Force test flights of lifting body re-entry vehicles. In three unmanned flights of the wingless aircraft, it was demonstrated that the lifting body could be maneuvered well away from its plotted re-entry path and then maneuvered back into that trajectory. This was a step toward the goal of developing technology for reusable spacecraft that will be capable of taking off like aircraft, carrying out space missions, and returning to land under pilot control.

The MANNED ORBITING LABORATORY (MOL) program of the Department of Defense moved into engineering development early in 1967. All principal components of the system progressed on schedule, a static test firing of the first-stage engine of the system's TITAN IIIM launch vehicle was carried out successfully, and construction of the MOL launch complex at Vandenberg AFB was begun. This spacecraft is intended to contribute to our national security. It has, however, no missions as a weapons system.

In furtherance of the desire of the United States and other nations for peace, the Treaty on Outer Space was approved without dissent by the Senate on April 25 and went into formal effect on October 10, when ceremonies were conducted in Washington, London, and Moscow. Also, the United Nations General Assembly unanimously passed an agreement on December 19, providing for assistance in the rescue and return of astronauts as well as of their space equipment. The agreement is now subject to approval by member governments.

Numerically, the U. S. space activity showed fewer spacecraft launched during 1967 than in either of the two preceding years. Yet, the 87 successes accomplished a variety of missions in near-Earth orbit as well as in lunar and planetary exploration. It was a year of high reliability in both launch vehicles and spacecraft, reaching a peak with the APOLLO flight on the mighty SATURN V, the world's most powerful rocket in operation.

The Soviets' over-all space effort was stepped up during the year, with 67 payloads successfully launched, compared with 51 for the preceding year. On April 24, the USSR suffered the first fatal accident in space when a SOYUZ spacecraft crashed on re-entry during its 18th orbit, killing its pilot. This accident prompted an investigation and a resultant delay of undetermined duration in the Soviet manned program. Among the USSR's notable successes of the year were the soft-landing of VENERA 4 on that planet on October 18 and the automatic docking of two unmanned spacecraft on October 30.

In the U. S. space program, 1967 was a year of milestones in applying space technology to the solution of man's problems. Progress was made in every category of applications satellites, with mounting attention being given to Earth observation capabilities.

Three U. S. weather satellites were launched to maintain the efficient operation of our weather satellite system. Routine, reliable pictures of the Earth's cloud cover were acquired daily and used by the Weather Bureau and the military services. Broad international acceptance of the Automatic Picture Transmission feature of the system was shown by the establishment of 150 new APT ground stations throughout the world during the year, bringing the total such stations to 300.

On January 11, NASA launched the first successful INTELSAT II satellite for the Communications Satellite Corporation, providing a commercial communications link between the U. S. mainland, Hawaii, and Japan and other parts of the Far East. The transatlantic link was supplemented by an INTELSAT II spacecraft on March 22, and still another was put into orbit over the Pacific on September 28. History was made in television and satellite communications on June 25, when a live telecast contributed to by 14 countries was carried to viewers in 26 countries via satellites.

On July 29, the TRANSIT navigation satellite system was declared available for commercial and other civilian use.

As significant as any 1967 development in the national space program has been the growing attention by government and private industry to the benefits flowing from the useful applications of space-influenced management techniques, hardware, and technology to the solution of social and economic problems. Moreover, there has been a gradually accelerating effort to apprise the general public of the manner and the extent of how the taxpayer gains from a vigorous and continuing space investment.

A summary list of aerospace accomplishments by the United States in 1967 includes the following:

1. In its first flight test, SATURN V, the world's largest operational rocket with 7,500,000 pounds of thrust, placed an APOLLO spacecraft into orbit.

2. The LUNAR ORBITER program was completed, having obtained photographic coverage of the front and hidden faces of the Moon, including eight prospective landing sites for astronauts.

3. SURVEYOR soft-landed on the lunar surface and transmitted the information that its composition is a type of material which is strong enough to hold a manned spacecraft for lunar exploration.

4. MARINER V flew-by within 2,600 miles of Venus and transmitted valuable data on the planet's environment.

5. Three TITAN IIIC boosters successfully placed 19 payloads into high orbits, some beyond synchronous distances.

6. Actual construction was begun on the first two prototypes of the Supersonic Transport, which will enter commercial operations in the 1970's.

7. Work on the C5A, the world's largest aircraft, progressed so that the aircraft is expected to be ready for roll-out in February, 1968, and make its initial flight in June of that year.

8. A new world speed record of 4,534 miles per hour was set in an X-15 rocket plane.

9. The first APPLICATIONS TECHNOLOGY SATELLITE successfully completed a year of complex experiments in communications, meteorology, and environmental physics. A second spin-stabilized ATS was put into synchronous orbit over the Atlantic and obtained impressive color pictures of the Earth.

10. NASA launched three communications spacecraft for the Communications Satellite Corporation to expand commercial satellite communications over the Atlantic and Pacific.

11. The geodetic satellite PAGEOS provided measurements for the accurate location of geographic points around the world.

12. Two EXPLORER and three OBSERVATORY satellites continued measurements of the Earth's environment, while another PIONEER probe was launched to measure interplanetary phenomena.

13. BIOSATELLITE II, which was safely recovered from orbit, carried a variety of life forms around the Earth for nearly two days, yielding information which will assist in planning for prolonged flights of astronauts.

14. The MANNED ORBITING LABORATORY program advanced through its engineering development phase.

15. The Outer Space Treaty entered into force; and the UN General Assembly unanimously approved an agreement on the emergency rescue and return of

astronauts and spacecraft, which agreement is subject to endorsement by individual governments.

16. The NERVA nuclear reactor was successfully tested in full-power operation for more than 60 minutes, about twice as long as in previous trials, adding to the evidence that rocket reactors will be useful in future space flights. The PHOEBUS-1B experimental reactor was operated for 30 minutes at nearly 1,500 megawatts.

17. Major components of the SNAP-8 nuclear auxiliary power system for space underwent over 2,500 hours of endurance tests.

18. Fueling of the first SNAP-27 space electric generator heat source was completed, as was component acceptance testing of the first flight generator (unfueled). Plans call for SNAP-27 to be placed on the Moon by an astronaut to provide power for lunar experiments.

19. Lasers were used to track near-Earth satellites with an accuracy within 5 feet; also tests proved the feasibility of using lasers to transmit video pictures from points as distant as Mars.

20. Two VELA nuclear-test detection satellites were placed into orbit to continue test-ban treaty monitoring.

21. Three ESSA weather satellites were launched to continue an operational system established in 1966, providing daily cloud-cover photographs to ground stations throughout the world.

22. The TRANSIT navigation satellite system was declassified and made available for commercial and other civilian use.

23. The 260-inch-diameter solid rocket motor, largest single rocket motor ever tested, was successfully static-fired. The motor generated a peak 5.8 million pounds of thrust in a firing of 80 seconds duration.

24. Through 1967, 84 countries were participating in cooperative space activities with the United States. Nine satellites had been successfully launched for five foreign nations and eight other satellites were under development for future launch. In addition, 124 scientists from 26 countries were taking part in space research at NASA centers; 19 countries were involved in cooperative sounding rocket programs; and 43 countries had Automatic Picture Transmission facilities to obtain cloud-cover pictures directly from U. S. satellites.

25. The U. S. launched a total of 87 spacecraft into Earth orbit and on escape trajectories.

NATIONAL AERONAUTICS AND SPACE COUNCIL

CHAPTER II

INTRODUCTION

The National Aeronautics and Space Council, established by the National Aeronautics and Space Act of 1958, has a statutory responsibility for advising and assisting the President with respect to the entire field of aeronautics and space policy programming and performance. The Council surveys and evaluates all significant U. S. aeronautical and space activities, develops comprehensive programs for such activities, and provides coordination between the various agencies involved in these programs.

During 1967, the Council carried out its responsibilities in a variety of fields whose scope was national in dimension, and international in extension. Its work encompassed both civilian and military aerospace projects.

THE VICE PRESIDENT

The Vice President, by statute, is the Chairman of the National Aeronautics and Space Council. In addition to presiding over all meetings of the Council held during the year, the Vice President visited numerous aerospace facilities, and acquainted himself at first hand with the complex ramifications of this vital growth in technological and management competence. Special emphasis was placed by the Vice President on the utilization of space technology to increase the well-being of the people in this nation and on the extension of such benefits to the world, to improve our international relations and strengthen world peace.

Continuing interest was expressed by the Vice President in the pace and scope of advances in aeronautics, particularly in new aircraft, air safety, and the reduction of aircraft noise and sonic boom.

BENEFITS

One of the major goals of the national space program is to apply the technology required for space conquest to better living here on Earth. By its stimulus to invention and demand for technological excellence, the space program has provided this nation with a broad range of skills unequalled anywhere else in the world. Such skills are the hallmark of national leadership in this century, which is based more than ever before on managerial, scientific, and engineering excellence. In such development, constructive cooperation between the Federal Government and private enterprise has been and is characteristic and basic.

The United States, in return for its investment in space amounting over the past ten years to less than one percent of our Gross National Product, has received an inflow of positive contributions to the national security, broadened technological skills, new products, markets and services, economies resulting from improved weather prediction, new and more economical modes of worldwide communications, enrichment of the quality of education, and buttressing of world peace through furtherance of international amity and cooperation.

Through our aerospace activities, the people of the world have been presented a positive image of a vigorous, progressive nation, dedicated to and succeeding in the attainment of excellence. Such performance reinforces the thesis that the individual nation which can offer freedom, encourage and reward enterprise, and provide a government responsive to the needs of all the people is the most successful.

SPACE PLANNING OBJECTIVES

In evaluating the national space program in terms of both present accomplishments and future goals, the Council has been guided by certain broad mission objectives. These include:

a. Applying the results of space research, technology, and discovery to achieve a variety of economic and social benefits.

b. Actively pursuing research and development to increase our knowledge of the space environment and fundamental facts of nature, and to make practical application of such knowledge.

c. Mastering the technology of advanced unmanned and manned flight to attain the capacity for ultra-high-speed, safe, and economical flight in outer space.

d. Conducting unmanned and manned exploration of the solar system, including the Moon and other celestial bodies.

e. Developing and applying space competence so that exploration and discoveries in space will enhance our capability to keep the peace and deter aggression on Earth.

f. Accelerating the development and operational use of space systems in meteorology, communications, navigation, geodesy, Earth resources inventory, and other Earth-oriented fields.

g. Seeking increased international cooperation in, and mutually advantageous agreements for, the use of outer space for peaceful purposes, development of a regime of law for outer space, joint and coordinated space endeavors, and orderly and open conduct of space, space-related, and aeronautical activities.

h. Striving for elimination of waste, minimization of duplication, and increase of cooperation in carrying out the national space effort.

AERONAUTICS

The research program for aircraft noise abatement has been extended by all competent agencies to embrace airframe and engine design for new airplanes, as well as the retrofitting of current equipment and pilot retraining where that can be productive.

NASA, the Department of Defense, and the Department of Transportation are expediting coordinated research into every aspect of equipment and control to improve air safety, particularly in the vicinity of large centers of concentrated air traffic.

Progress continues in constructing two SST prototypes to be ready for flight tests in 1970. Continuing attention is being given to increasing the safety features and decreasing the noise level and sonic boom.

COMPARISON OF U. S. AND SOVIET SPACE PROGRAMS

The United States put 77 payloads into Earth orbit and 10 payloads on escape missions during 1967. USSR figures for the same period were 66 and 1 respectively. Over the past 10 years, since the first successful launch into space, U. S. total payloads have been 542 and the number for the USSR 284. Although the United States has placed the largest weight into orbit on a single launch with the world's most powerful rocket, the SATURN V, the Soviets are estimated to have orbited greater total weight over the years than the United States. High priority is given to space activity by both nations, with considerable indication that the Soviets give it higher priority than the United States in terms of relative investment of gross national product. The Soviets have begun to show considerable interest in the space application fields in which the United States has had so much success, particularly in meteorology, communications, and navigation. The vigor, competence, and broad approach of the USSR aerospace program demonstrate that the United States has no grounds for complacency regarding its technological or performance leadership.

COUNCIL ACTIVITIES

During Calendar Year 1967 the Council and its staff dealt with a variety of aerospace problems. A number of meetings were held to exchange inter-agency information and evaluate views regarding FY 1968 and FY 1969 budget plans. Special consideration was given to post-APOLLO space goals, the APOLLO capsule fire, foreign-affairs aspects of U. S. space programs and opportunities for expanded international cooperation in outer space, coordination of the U. S. presence in major international scientific and cultural events having an aerospace content, plans and prospects for natural resources satellites, policy aspects of communications satellite development, planning and safety aspects of nuclear rocket and space nuclear-power projects, aeronautical research funding, aeronautical safety, and reduction of airport noise.

In brief, the Council directly and through its staff engaged in a broad range of policy, coordinating and informational activities. Among these were:

a. Supervised and edited the President's Annual Report to the Congress on Aeronautics and Space Activities for 1967.

b. Submitted regular reports to the President and the Council Chairman on significant space activities and plans.

c. Maintained a mutually informative relationship with members and staff of appropriate committees of the Congress on aeronautics and space developments here and abroad.

d. Increased public understanding of the national space program through speeches, articles, correspondence, and other public contacts.

e. Participated in analysis of and made recommendations concerning budgets for space and aeronautics.

f. Coordinated for the President the decisions involved in launching nuclear power units in spacecraft.

g. Helped to develop policy recommendations on the growth of communication satellite systems.

h. Examined the status and potential of Earth resources satellites.

i. Surveyed the relative capability and state of development of onboard space power supply alternatives.

j. Furnished briefing materials, including space photographs, for use in connection with visits to Washington of high-ranking officials of other nations.

k. Participated in the planning for aeronautical and space exhibits abroad.

l. Examined the need for legislative changes affecting space and aeronautics.

m. Maintained liaison with the technological and aerospace communities.

n. Reviewed the status of meteorological, navigation, communication and applications technology satellite projects.

o. Visited space installations, examined facilities, and engaged in inter-agency as well as Government-industry meetings and briefings on new developments in aeronautics, space technology, and space benefits.

p. Maintained a current record of U. S. and Soviet space launches, developed comparisons between U. S. and USSR space activities, and reviewed the space accomplishments and potentials of other nations.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHAPTER III

INTRODUCTION

During 1967, the National Aeronautics and Space Administration made worthwhile progress in its wide-ranging scientific and technological programs in space and aeronautics. Of special interest was the collecting of vital information about the surface and environment of the Moon.

Although the APOLLO fire of January was a serious blow to NASA's manned space flight program, knowledge gained from it brought about changes in procedures, improvements in engineering, and a strengthening of safety precautions. Such developments, along with the great success of the SATURN V on November 9, furnished a basis for optimism and encouragement.

In the space science and applications program, automated spacecraft photographed the entire front and hidden faces of the Moon to point out possible landing sites for astronauts. Other unmanned spacecraft landed on the lunar surface and found that its earthlike soft stone was strong enough to support manned landings, and that its environment was not too hostile for men to explore it.

Extending scientific investigations millions of miles away, still another spacecraft flew within 2, 600 miles of Venus to send back invaluable data about the planet and interplanetary space.

Three more weather satellites were added to the operational meteorological network, experiments with communications satellites were carried out successfully, and a geodetic satellite supplied measurements for precise location of geographic points around the world. An ORBITING GEOPHYSICAL OBSERVATORY and two ORBITING SOLAR OBSERVATORIES were launched. The second BIOSATELLITE (an orbiting biological laboratory) studied the effects of almost two days in space on various life forms to prepare for extended manned flights.

Advanced research and technology efforts concentrated on seeking out answers to current aeronautics and space problems and anticipating those of the future. Although tragedy struck the 191st flight of an X-15, these airplanes were used extensively for hypersonic speed and high-altitude experiments; the XB-70 made a number of flights to collect data on the sonic boom and other subjects related to the SUPERSONIC TRANSPORT; and studies of V/STOL aircraft included wind tunnel and laboratory investigations and research on propulsion concepts. The aircraft noise alleviation program began inquiries on engine nacelle modifications as a means of minimizing noise and on the technology for a quiet engine.

A 260-inch-diameter solid motor developed over 5.8 million pounds of thrust in an impressive test firing.

Nuclear research also advanced. The joint NASA/AEC nuclear rocket program ran tests in which three separate reactors were operated for up to 30 minutes at powers above 1,000 megawatts, one approaching 1,500 megawatts, and the NRX-A6 reactor was successfully tested at full power of about 1,100 megawatts for more than 60 minutes. The SNAP-8 program accumulated more test hours than in all previous years combined--2,500 hours or better for all major components, except boiler and turbine.

MANNED SPACE FLIGHT

Attention on manned space flight was concentrated on the APOLLO Program, with particular emphasis on the technical and engineering improvements identified as necessary following the APOLLO 204 accident. In addition, planning continued for the follow-on APOLLO Applications Program.

APOLLO Program

At year's end, the APOLLO Program was again proceeding soundly toward the attainment of its lunar objective following the success of the APOLLO 4 flight-test mission in November. For months prior to this, however, the program was recovering from a major blow -- the accident in January in which an APOLLO crew was lost. As a result of that event, substantial technical and operating changes were made.

First SATURN V Flight Test (APOLLO 4) -- A milestone of the first magnitude was reached on November 9, with the successful first unmanned Earth-orbital flight-test of the APOLLO-SATURN V space vehicle.

This mission marked the achievement of several key "firsts": The first launch from the Kennedy Space Center Launch Complex 39; first flight of the integrated APOLLO-SATURN V space vehicle; first flight of the first stage (S-IC) and second stage (S-II) of the SATURN V launch vehicle; first engine restart in orbit of the upper stage (S-IVB) of the SATURN vehicle; and first demonstration of an APOLLO spacecraft re-entering the Earth's atmosphere at the speed of a spacecraft returning from a mission to the Moon.

The principal objectives of the mission were to obtain flight information on launch vehicle and spacecraft structural integrity and compatibility, flight loads, stage separation, subsystem operation, and emergency detection subsystem operation; and to evaluate the APOLLO COMMAND MODULE heat shield under conditions encountered on return from a lunar mission. The APOLLO 4 mission also tested the thermal seals to be used in the new, outward-opening, quick-release hatch for the manned COMMAND MODULES.

The APOLLO 4 lifted off at 7:00:01 a.m., one second after the planned time. All three stages of the SATURN V launch vehicle fired properly, and the APOLLO spacecraft and the launch-vehicle third stage (S-IVB) were placed into a 115-statute-mile circular orbit. After completing two orbits, the third stage was ignited a second time to place the spacecraft into an orbit with an apogee of about 10,800 statute miles.

After separating from the third stage, the spacecraft raised its apogee to more than 11,000 statute miles by firing its service propulsion system (SPS) engine. A second SPS burn during descent from the apogee boosted the re-entry velocity to 25,000 statute miles-per-hour for the spacecraft COMMAND MODULE (CM). The SERVICE MODULE (SM) was separated from the CM before re-entry.

The CM, protected by its heat shield, re-entered the atmosphere and was recovered about 600 statute miles northwest of Hawaii. Elapsed time of the mission, from liftoff to landing, was eight hours, 37 minutes, and eight seconds.

The APOLLO-SATURN V, 363 feet tall, is the most powerful space vehicle ever known to have been launched. Its first-stage engines produced 7,500,000 pounds of thrust at liftoff. The fully fueled vehicle weighed 6,220,025 pounds at launch. Total weight put into orbit was 278,699 pounds.

APOLLO 204 Fire -- On January 27, a tragedy occurred at Kennedy Space Center when fire erupted inside the APOLLO 204 spacecraft during ground testing. The fire resulted in the deaths of astronauts Virgil I. Grissom, Edward H. White, III, and Roger B. Chaffee.

After two and one-half months of investigation, the APOLLO 204 Review Board of Inquiry determined that the most likely cause of fire was electrical arcing from certain spacecraft wiring.

As a result of the accident, extensive redesign and modification of the COMMAND MODULE were required. Knowledge gained as a result of the fire and in subsequent testing led to alteration both in the selection of spacecraft materials and in their placement within the vehicle.

Other major areas of change involved the quick-release hatch, the Earth landing system, crew equipment and couches, and protective coverings for exposed plumbing and electrical harnesses. Redesign and modification of the LUNAR MODULE were not as extensive as those on the COMMAND MODULE and primarily involved material changes. Scheduled deliveries of both spacecraft were delayed to accomplish additional testing, retesting, and re-qualification of the modified hardware.

APOLLO Flight Program -- Because of the 204 accident, the APOLLO Program underwent extensive replanning to accommodate the changes to the Block II COMMAND-SERVICE MODULES and LUNAR MODULES necessary for manned flight. There was substantial rephasing in the program, and some APOLLO launches originally scheduled for 1967 were deferred.

A schedule of major flight phases was established in 1966 for APOLLO. The first phase--that of unmanned flights of the APOLLO-Uprated SATURN I vehicle--was successfully completed in 1966, on schedule. The next phase--unmanned APOLLO-SATURN V flight tests--was begun in 1967 as planned, with the APOLLO 4 mission.

The unmanned flight testing of the LUNAR MODULE with the Uprated SATURN I, originally scheduled for 1967, was deferred and is now scheduled for early 1968. Manned operations with the APOLLO-Uprated SATURN I, previously planned for 1967, have been deferred to the third quarter of 1968.

Manned APOLLO-SATURN V flights are scheduled to start in late 1968. Manned lunar mission simulations with the APOLLO-SATURN V are scheduled in 1969, leading to a planned lunar landing mission prior to the end of 1969.

Forthcoming Launches -- APOLLO 5: The objective of the unmanned APOLLO 5 mission is to verify the operation of the LUNAR MODULE ascent and descent propulsion systems, and the LUNAR MODULE structure.

The Uprated SATURN I launch vehicle for the APOLLO 5 mission is designated SA-204, and the payload will be LUNAR MODULE LM-1 and a nosecone. This major test flight is scheduled for early 1968.

APOLLO 6: The mission objective of the unmanned APOLLO 6 is to qualify the SATURN V launch vehicle facilities and procedures and the Block II COMMAND MODULE heat shield. The flight will also test the new Block II hatch design. The SATURN V launch vehicle for the APOLLO 6 mission will be SA-502, while the COMMAND MODULE is CSM 020. The launch is scheduled for the first half of 1968.

First manned APOLLO flight: The first manned flight in the APOLLO Program will use an Uprated SATURN I launch vehicle and the first Block II COMMAND AND SERVICE MODULE (CSM 101). This mission is scheduled for late summer of 1968.

First manned APOLLO-SATURN V flight: The first manned SATURN V mission is scheduled for late 1968.

Uprated SATURN I -- The delivery of stages for the Uprated SATURN I launch vehicle was nearing completion at year's end. The program encountered no significant technical problems.

The SA-204 launch vehicle, for the APOLLO 5 flight, was "stacked" at KSC's Launch Complex 37B, and, at year's end, was in final preparation for the unmanned LUNAR MODULE development flight early in 1968.

SATURN V Launch Vehicle -- The dynamic testing of the total SATURN V vehicle at Marshall Space Flight Center was completed during the year.

Two lines in Launch Complex 39 (LC 39) at KSC have been completed. This includes, for each line, the High Bay in the Vehicle Assembly Building, the Firing Room in the Launch Control Center, and the Mobile Launch Umbilical Tower.

Major technical and production problems in the second stage (S-II), reported last year, including surface imperfections in the structure and in the welds, have been satisfactorily resolved.

An S-II Confidence Program was completed in April, 1967. This program included five firings of the S-II "battleship" stage and two firings on each of the first two flight stages. The first two S-II flight stages were delivered to KSC and erected during 1967.

The SA 502 launch vehicle, to be used on the APOLLO 6 mission, was assembled in the Vehicle Assembly Building at KSC, and is being readied to launch the unmanned Block I CSM 020 in 1968.

COMMAND AND SERVICE MODULE -- All of the changes resulting from the APOLLO 204 accident are being incorporated in the Block II spacecraft. Major changes were made in the materials, wiring, plumbing, hatch, crew equipment, crew couches, and emergency oxygen and fire suppression equipment. These changes required a realignment in the ground-test program and the addition of new tests including flammability propagation tests.

Review and selection of materials to conform with established flammability criteria has been a major effort. Weight growth stemming directly from the changes made as a result of the accident has required redesign of the parachutes in the Earth-landing system and a re-evaluation of the emergency-recovery mode of land impact.

In summary, the changes in the Block II spacecraft were extensive, and constant effort was required to re-establish the program momentum that had been attained prior to the accident.

LUNAR MODULE -- The first LUNAR MODULE (LM) flight article was delivered to KSC on June 23, 1967.

As in the case of the SERVICE MODULE, changes in design and materials were made in the LM as a result of the accident. This has taken time.

A major problem was a combustion instability in the LM ascent engine. To cope with this, design changes were made in the engine injector and a back-up program with an alternate design was instituted. The ascent engine will require further test before it is qualified for manned flight.

Another problem involved leaks in the fittings of the propellant lines in LM-1. Changes were made in the connections and seals, and tests were successfully run, indicating that the problems were resolved. The spacecraft was moved to the launch pad and mated with the launch vehicle on November 15.

APOLLO Applications Program

Work proceeded in support of the basic objectives of the APOLLO Applications Program: to conduct long-duration space flights of men and systems; to perform scientific investigations in Earth orbit; to conduct Earth-orbital missions, such as meteorology, communications, and Earth resources surveys; and to conduct extended lunar exploration.

During the year, significant effort was carried out in a number of areas in preparation for the approved AAP missions. By the end of the year, hardware development was well under way for the early Earth-orbital missions, as well as experiment development and operations planning. Eighty-seven experiments for AAP missions were approved by year's end.

In particular, work was accomplished on two major experiments in APOLLO Applications--the Orbital Workshop and the APOLLO Telescope Mount.

The Orbital Workshop is the empty upper stage of a SATURN launch vehicle, converted into a habitable space structure for long-duration missions. Astronauts will be able to enter and leave the Workshop through an airlock, after rendezvous and docking with an APOLLO spacecraft.

The APOLLO Telescope Mount is a set of observational equipment, consisting of a group of telescopes and other instruments, mounted on a rack attached to a LUNAR MODULE.

LUNAR AND PLANETARY PROGRAMS

SURVEYOR

Exploring the Moon's surface and photographing the potential landing areas, the SURVEYOR I, III, V and VI soft-lander spacecraft transmitted vital and heretofore unobtained data. Among the findings were that:

-- A lunar bearing strength of 3 to 8 pounds per square inch in certain areas could support the APOLLO manned spacecraft.

-- This manned spacecraft could then adapt to the topography and surface conditions after landing in one of these areas.

-- Dust on the lunar surface probably would not bother astronauts.

-- The surface--a soft stone composed of oxygen, carbon, silicon, sodium, magnesium, aluminum, sulfur, and an iron-cobalt-nickel combination--is similar to the basalt found commonly on Earth.

SURVEYOR III, launched from Cape Kennedy on April 17, soft-landed in a crater in the Sea of Storms two days later. By the end of the first lunar day (two Earth weeks) the spacecraft had responded to over 30,000 commands and sent back 6,315 pictures, some of itself and its immediate vicinity, and the first color photo of an eclipse of the Sun by the Earth. Sampling the lunar soil, it dug four trenches -- the largest 2 inches wide, 10 inches long, and 7-1/2 inches deep.

SURVEYOR IV was launched on July 14. Its flight was flawless until approximately 3 minutes prior to landing, at which time contact was suddenly lost with the spacecraft. An investigation failed to determine the cause of the failure. Since the chance of the failure recurring was considered to be slight, the next mission was not delayed and no significant hardware changes were made.

SURVEYOR V was launched on September 8 and landed on the lunar surface in the Sea of Tranquility three days later. During the first lunar day the spacecraft returned a total of 18,006 high-resolution pictures of the surrounding area--more than the combined totals of SURVEYORS I and III. In addition, the spacecraft's alpha-scattering instrument transmitted 83 hours of high-quality data on the relative abundance of chemical elements in the lunar surface, the first on-site compositional analysis of an extraterrestrial body.

A small magnet carried by this SURVEYOR showed that magnetic material was present in about the same amount as found in the basalt in the Earth's crust.

SURVEYOR V survived the deep freeze of the two-week lunar night and was reactivated for limited operation during the second lunar day.

SURVEYOR VI was launched on November 7, and landed on November 9 in the rugged terrain of Sinus Medii (Central Bay). During its operation over the first lunar day it transmitted more than 30,000 photographs, conducted a chemical analysis of the lunar surface material, and under Earth command lifted off and moved about 10 feet to a new location. This was the first time such a maneuver had been carried out on the Moon.

LUNAR ORBITER

All five LUNAR ORBITERS were successful. The final three of the five LUNAR ORBITER photographic missions were carried out successfully during the year as scheduled.

LUNAR ORBITERS I, II, and III spacecraft provided sufficient photographic coverage of potential landing sites on the front side of the Moon to make possible the selection of eight candidate sites for the first APOLLO landings. LUNAR ORBITER IV, in turn, supplied complete detailed coverage of the front side, and the last spacecraft in the series augmented the total data obtained from this highly successful program.

Additional data on micrometeoroid flux and radiation dose levels near the Moon were also obtained from each mission. Radio tracking data from all five spacecraft were used as a basis for an improved understanding of the lunar gravitational field. The series also helped to train and qualify tracking and data specialists of the Manned Space Flight Network to be used during the APOLLO missions.

MARINER

The MARINER V mission was planned to help determine the origin and nature of Venus and its environment, complementing data supplied during the MARINER II flyby in 1962. This MARINER also afforded engineers experience in converting a spacecraft designed for a flight to Mars into one flown to Venus, and then operating the new version. Further, it transmitted information on the interplanetary environment during a period of increasing solar activity.

MARINER V was launched on June 14 and flew within 2,600 miles of the Venusian surface on October 19. It measured interplanetary fields and particles and operated flawlessly during the entire mission to supply invaluable data. Some highlights were:

- Definite evidence of the interaction of the solar wind with Venus, the size of the interaction region being much smaller than for Earth and larger than for the Moon.

- No detection of energetic particles or radiation belts around the planet, indicating that the magnetic moment of Venus is less than 1 percent of Earth's.

-- Indications that the planet's atmosphere could be seven to eight times as dense as Earth's and possibly composed of 72 to 87 percent carbon dioxide, the remaining gas being nitrogen.

-- Evidence that the ionosphere of the planet's dark side is low in the atmosphere, less than 100 miles, and is thin. Preliminary information on the ionosphere of the lighted side of the planet indicates that it is at about the same height as the dark side.

-- No detection of oxygen in the vicinity of Venus.

MARINER IV -- Although it passed within 6,120 miles of Mars in July, 1965, MARINER IV continued to orbit the Sun, its solar panels still furnishing power. It came within range of the 210-foot antenna at Goldstone, California, early this year, and tracking and telemetry were resumed. The spacecraft appeared to be operating about as it had late in 1965. In August and September, when the two spacecraft were similarly aligned with the Earth and Sun, MARINER IV operated with MARINER V to study solar energy propagation.

MARINER IV came closest to Earth on September 8 (29.2 million miles). On September 16, it survived a micrometeorite shower with no apparent permanent damage.

On October 26, its pictures of Mars obtained in 1965 were played back from the spacecraft's tape recorder to evaluate the performance of equipment which had been in interplanetary space for almost three years.

Two MARINER spacecraft are to be launched around March, 1969, and encounter the planet early in August. Each will make a variety of scientific observations with remote sensing instruments during fly-by. These instruments--which are now designed and in various phases of test--will provide data on the planet's physical, chemical, and thermal properties, as well as take pictures.

The spacecraft itself will act as an instrument, since its path will be influenced by the gravity pull of Mars, enabling scientists to better determine the Earth-Mars geometry. Also, as the spacecraft passes behind Mars its radio signals will provide data on the pressure and temperature of the atmosphere.

With a much increased data return rate and a reprogrammable computer, the new spacecraft will afford a choice of mission options. One would be to start TV cameras two or three days before encountering the planet, and thus obtain photographic coverage of the entire Martian surface.

VOYAGER

Preliminary design of the VOYAGER spacecraft, which was to perform experiments on the surface of Mars in 1973, was completed in November. This spacecraft would also orbit Mars to obtain data to help determine whether life is present and to supply information on the Martian atmosphere, surface, and environment.

The three prime contractors studying the spacecraft system continued to develop detailed preliminary designs for launching two VOYAGERS aboard one SATURN V.

Two other prime contractors performed detailed preliminary designs of the capsule system for soft-landing on Mars, leading to detailed designs for the capsule bus and surface laboratory systems.

Because of budgetary arrangements, further effort on the VOYAGER program will be deferred.

APOLLO Lunar Surface Science Program

Tests of the engineering model of the APOLLO Lunar Surface Experiments Package (ALSEP) and its eight experiments were completed during 1967. They proved that the basic designs of this geophysical station's electronics were sound. ALSEP will be placed on the Moon by APOLLO astronauts, and it will transmit data to Earth for a year on the magnetic fields of the Moon; the lunar interior, thickness, and density; the charged-particle environment of the Moon; and the pressure and composition of ions in its atmosphere.

A miniaturized seismic station (the ALSEP Passive Seismic Experiment) was developed to record lunar "earthquakes." Weighing less than 25 pounds and able to stand the rigors of the lunar environment, the seismic station is one-tenth as heavy as a typical Earth-based station to record earthquakes.

In addition, the development of Lunar Geological Equipment (LGE)--tools, cameras, and lunar sample return containers--continued on schedule.

SPACE SCIENCE AND APPLICATIONS

An APPLICATIONS TECHNOLOGY SATELLITE completed a year of complex experiments in communications, meteorology, and environmental physics, and the third ATS transmitted color pictures of the full Earth's disc. Three more weather spacecraft joined the national operational meteorological network to provide more comprehensive data on global cloud cover. A large geodetic satellite supplied measurements for the accurate location of geographic points around the world.

Two ORBITING SOLAR OBSERVATORIES and an ORBITING GEOPHYSICAL OBSERVATORY were launched. And an orbiting biological laboratory--BIOSATELLITE--investigated the effects of space on various life forms to prepare for prolonged manned flights.

Orbiting Observatories

ORBITING SOLAR OBSERVATORIES (OSO) III and IV were launched on March 8 and October 18. OSO III experiments were examining X-rays, ultraviolet light, and infrared radiation coming from the Sun. The satellite was also measuring cosmic rays and extreme ultraviolet radiation from the Sun. Experiments carried by OSO IV concentrate on solar radiation of shorter wavelengths than those being measured by OSO III. In addition, OSO IV can scan the Sun to locate radiation sources.

The fourth ORBITING GEOPHYSICAL OBSERVATORY (OGO IV) was launched on July 28 into an orbit ranging between 256 and 564 miles. The 1,240-pound satellite is stabilized to provide a platform from which its instruments can look toward the Earth, space, and Sun. A nearly-polar orbit permits its instruments to view the entire surface of the Earth once every 24 hours and make comprehensive measurements of the near-Earth environment during the present period of increasing solar activity.

Thirty-five of the 61 experiments of OGO I, II, and III (orbited in 1964, 1965, and 1966) were still supplying data on the behavior and transmission of phenomena in interplanetary space.

The second ORBITING ASTRONOMICAL OBSERVATORY (OAO II) was being prepared for a 1968 launch. OAO I--launched in April, 1966--was orbited as planned and carried out its first pointing operation. But, during its second day in orbit, faulty operation of a battery circuit deprived the spacecraft of power and it became useless.

EXPLORER Satellites

EXPLORERS XXXIV and XXXV, of the INTERPLANETARY MONITORING PLATFORM class, were measuring cosmic rays, solar plasmas, and magnetic fields in interplanetary space to further scientists' knowledge of Sun-Moon-Earth relationships.

In May, the 163-pound EXPLORER XXXIV was placed into a highly elliptical orbit that reached 133,000 miles from the Earth (about half-way to the Moon). Its orbit allows for studies of the magnetosphere during this period of increasing solar activity. EXPLORER XXXV, a 230-pound spacecraft, was inserted into a loose lunar orbit in July. This spacecraft was investigating the characteristics of the interplanetary magnetic field, solar plasma flux, interplanetary dust distributions, and solar and galactic cosmic rays in the vicinity of the Moon.

PIONEER

PIONEERS VI and VII, launched in 1965 and 1966, continued to provide interplanetary data from widely separated points in space. Communications with PIONEER VI were re-established after it passed behind the Sun and re-appeared. PIONEER VIII was launched on December 13, 1967, to supplement the data being received from its predecessors.

Sounding Rockets and Balloons

Sounding rockets were launched as experiments to study atmospheric composition, planetary and interstellar dust, micrometeorite flux, magnetic fields, aurora, cosmic radiation, stellar X-ray sources, ionospheric structure, and solar composition and radiation.

Five rocket flights tested: (1) instruments being developed for a West German research satellite to investigate the Van Allen radiation belts in 1969, and, (2) instruments for the OGO-E spacecraft to study energetic particle flux, very-low-frequency phenomena and neutron flux.

Fourteen flights were launched to carry out experiments to investigate atmospheric ozone, solar ultraviolet radiation, ionospheric structure and atmospheric nitric oxide, complementing experiments on OGO IV, OSO III, ISIS, and ALOUETTE II and being coordinated with flybys of these satellites. Also, two rocket-borne experiments were used to study hydrogen and ultraviolet radiation from Venus, their launching coordinated with the MARINER V flyby of the planet in October.

Scientific balloons conducted experiments in energetic particle flux, magnetic fields, cosmic radiation, micrometeorite flux, interplanetary and circumsolar dust, and X- and gamma ray-astronomy. Some flights carried out experiments using instruments being developed for the OGO, OSO, IMP, and PIONEER satellites. One balloon-borne experiment reported concentric shells of dust around the Sun.

BIOSATELLITES

BIOSATELLITE II was launched on September 7 into a circular orbit about 195 miles above the Earth and recovered 45 hours later by an airplane in mid-air over the Pacific. It carried 13 experiments to study the biological effects of weightlessness and of weightlessness combined with an onboard radiation source. Among these biological experiments were wheat seeds whose roots showed disorientation while germinating in space and pepper plants whose leaves bent downward rapidly and stems curved.

Experiments on radiation combined with weightlessness showed increased radiobiological effects. For example, there were 50 percent more mutants (wing abnormalities in adults developing from eggs laid in space) than in irradiated ground controls at 1 g. Drosophila larval chromosomes showed abnormal pairing and aberrations never before observed. Also, wasp eggs were delayed in development and were protected against radiation damage. Other biological effects of weightlessness and radiation were observed, to make this space flight a major scientific accomplishment.

APPLICATIONS TECHNOLOGY SATELLITES

The first APPLICATIONS TECHNOLOGY SATELLITE (ATS-I), launched in December, 1966, continued to operate successfully throughout 1967. Its experiments have demonstrated the feasibility of two-way voice communications with aircraft, multiple-access communications techniques, trans-Pacific color TV transmissions, nearly continuous daylight observation of Earth cloud cover, and transmissions of weather data to simple inexpensive ground readout stations.

On April 5, NASA orbited ATS-II--the first three-axes gravity-gradient-stabilized spacecraft. This satellite failed to achieve its planned 6,000-mile circular orbit due to a launch vehicle malfunction. No data on gravity-gradient stabilization performance were obtained, but useful information was provided by four of the scientific experiments.

The second spin-stabilized ATS (ATS-III) was launched into geostationary orbit over the Atlantic Ocean on November 5. The spacecraft carries advanced sensors and instruments to conduct experiments in communications, navigation, data collection and relay, meteorology, and environmental physics.

Two more satellites in the series (ATS-D and -E) were being developed. These will be gravity-gradient-stabilized and include a day-night camera and a number of experiments for surveying environmental conditions at geostationary altitude.

Communications Satellites

NASA launched three INTELSAT-II satellites for the Communications Satellite Corporation during the year. Two of these were placed over the Pacific to link Asia and Australia with North America; the third was orbited over the Atlantic to link Europe and North America. The satellites are providing commercial service and will also support the APOLLO lunar landing program. This is a major operational application of space technology.

Meteorological Satellites

ESSA and TIROS -- To continue the nation's operational meteorological satellite system, NASA launched three TIROS Operational Satellites for the Environmental Science Services Administration (ESSA). Two of them, ESSA 4 and 6, provide local cloud pictures to Automatic Picture Transmission (APT) users around the world. The other, ESSA 5, carries two Advanced Vidicon Camera Systems to supply daily global daytime cloud cover pictures to national users.

NASA, in conjunction with ESSA, began to develop the next generation of operational weather satellites (TIROS M). This satellite will incorporate sensors able to provide both direct readout and stored cloud-picture data during the daytime and at night. These sensors were developed and flight-tested on the NIMBUS satellites.

NIMBUS -- The NIMBUS II satellite, still operating satisfactorily, completed 19-1/2 months in orbit on December 31. The satellite was stabilized within ± 1° in three axes, and the remaining lifetime of its control gas supply was estimated at about 5 years. The APT system was operating and transmitting good-quality pictures to worldwide ground stations.

The third NIMBUS (NIMBUS B), scheduled for an early 1968 launch, was assembled and undergoing final integration and testing. In addition to remote sensors for measuring radiation reflected and emitted by the Earth and its atmosphere, it will carry a worldwide meteorological data collection system. A radioisotope thermoelectric generator (SNAP-19) will be tested on this spacecraft to determine the feasibility of using such a power source for meteorological satellites.

NIMBUS D continued on schedule for a 1970 launch. Work progressed on all major spacecraft subsystems and flight experiments.

The meteorological satellite program is one of the most beneficial of all space activities.

Sounding Rockets -- NASA launched 56 research sounding rockets to obtain meteorological measurements between 20 and 60 miles above the Earth. Acoustic grenades, pitot-static tubes, and light-reflecting or luminous-vapor experiments were used to gather data for studying the dynamics and structure of the upper atmosphere.

Geodetic Satellites

GEOS -- Launched in November, 1965, GEOS-I became essentially inactive as a geodetic instrument this year and is providing a limited amount of observational data. However, the satellite has supplied a significant amount of information from the five geodetic instrumentation systems on-board to help define Earth's gravitational field.

GEOS-B -- the next active geodetic satellite, scheduled for launch early in 1968 -- will carry the five geodetic instrumentation systems carried by GEOS-I and a C-band radar transponder to extend the range of its measurements.

PAGEOS -- A highly reflective 100-foot-diameter balloon of the ECHO type, PAGEOS completed over 1-1/2 years in orbit and was observed by more than 40 ground stations around the world. Ground-based observers using the balloon as an orbiting point source of light assisted in determining the position of geographic points for a global control reference system.

Data provided by geodetic satellites have helped to determine: the relative position of 12 of 75 control points needed to establish a unified worldwide geodetic reference system; about 50 percent of the latitude- and longitude- dependent coefficients to define worldwide variations of Earth's gravitational field; and the intercomparison of the geodetic satellite observational systems currently used by NASA and the Defense Department.

Earth Resources Survey Program

NASA, with the Departments of Agriculture, Commerce, Interior and Navy, continued to study the feasibility of using space-acquired data for surveying the world's natural and cultural resources. Aircraft flying various types of remote sensors (special cameras, infrared imagers, microwave radiometers, and radar) collected Earth resources data from an expanded network of ground test sites. Various government agencies used these data and information provided by the Project GEMINI and NIMBUS space-flight missions to develop analytical techniques for interpreting such information in terms of Earth resources phenomena.

NASA was also developing prototype instruments to gather remote sensor data defining meaningful experiments and determining space missions to collect and transmit a wide variety of Earth resources data. This program promises significant applications benefits.

LIGHT AND MEDIUM LAUNCH VEHICLES

During 1967 CENTAUR launched four SURVEYOR spacecraft to soft-land on the Moon. These were SURVEYOR III on April 17 -- the first dual-burn restart ascent trajectory flown by the vehicle; SURVEYOR IV (July 14); SURVEYOR V (September 8); and SURVEYOR VI (November 7).

THOR-DELTA launched three meteorological satellites for ESSA, three communications satellites for the ComSat Corporation, and six scientific satellites for NASA's Space Science and Applications Program. The scientific satellites included two of the EXPLORER class, two ORBITING SOLAR OBSERVATORIES, BIOSATELLITE II, and, PIONEER VIII.

The SCOUT was used in nine launch attempts, of which two were failures. Among the successes was the orbiting of the SAN MARCO B satellite on a SCOUT by the Italian Space Commission from its launch range off the coast of Kenya, Africa, concluding this phase of a joint program of NASA and this Commission.

AGENA continued to support automated space missions, completing five ATLAS-AGENA launchings and a THOR-AGENA launching. The LUNAR ORBITER program was concluded with three successful ATLAS-AGENA launches, marking five successes in five launch attempts in this program. MARINER V was successfully placed in a fly-by trajectory of Venus by an ATLAS-AGENA.

ATLAS-AGENA experienced its first failure in three years when an APPLICATIONS TECHNOLOGY SATELLITE failed to achieve its desired circular orbit due to a malfunction of the second stage. THOR-AGENA maintained its record of no failures with the launching of an ORBITING GEOPHYSICAL OBSERVATORY.

The first IMPROVED ATLAS for CENTAUR (the SLV-3C) was successfully flown on the SURVEYOR V launch in September. The first SLV-3A or IMPROVED ATLAS for AGENA was in its final stages of preparation for an early 1968 launch.

BASIC AND APPLIED RESEARCH

Fluid Dynamics

A coordinated research program was initiated to study the basic mechanisms which cause, and the parameters which influence, propagation of the sonic boom by supersonic aircraft. Specific problem areas were defined, and work was begun in each with the objective of minimizing this disturbance.

Laboratory simulation of clear air turbulence (CAT) showed that natural events can amplify, by a factor of 10, the low turbulence level produced by a small disturbance in the atmosphere, and that the result is a severe turbulence level in the clear air far from the small disturbance. It was also found that a temperature inversion in the atmosphere--warm air above cool air--tends to suppress the turbulence.

Fluid dynamic analysis techniques were applied to experimental data on blood flow through organs by injecting radioactive tracers into animals. The resultant theory agreed with experimental results and gave useful information on flow rate, blood volume, and mean transit time. This method will be useful for analyzing results of tests on the human circulatory system which can be interpreted to give an early indication of an impending stroke, heart disease, or other malfunction.

Electrophysics

Research on methods of raising the temperature at which a metal loses all electrical resistance indicated that the electron pairs responsible for superconductivity can be formed not only of electrons in the body of the metal (as is usual) but also of electrons initially separated from one another by a thin insulating barrier. Structurally, this new type of electron pairing was accomplished by interleaving thin-film layers of metal and insulator in a sandwich assembly. With layers of aluminum separated by silicon monoxide, the superconducting temperature increased to more than double its value in bulk aluminum. Other metals and alloys were being studied in an effort to increase the superconducting temperature still further.

Materials

A tungsten alloy with greatly improved strength and ductility was developed by adding small percentages of hafnium and carbon to improve strength and rhenium to improve ductility. The resulting alloy had a strength of over 75,000 pounds per square inch at 3,500°F, the highest strength ever reported for any metallic material at this high temperature. A tungsten alloy with such properties, in addition to tungsten's high melting point, could be used as a structural material for space power plants and rocket engines.

NASA made stress corrosion tests of titanium alloys desired for new supersonic aircraft under simulated supersonic flight conditions. The results indicated that corrosion found in the still air and normal pressure of the laboratory would not occur under the expected flight conditions, but that when future aircraft fly much faster than about Mach 3 there may be corrosion trouble.

The Lewis Research Center developed an ultra-long chain plastic which has chains four times the length of those of commercial plastics. Since the mechanical properties of plastics improve as the length of the chain is increased, the newly developed material should have better very-low-temperature properties and be suitable for such space uses as liners and bladders in liquid-hydrogen propulsion systems.

AERONAUTICS

Aircraft Aerodynamics

Langley Research Center conducted analytical and wind-tunnel tests on a supercritical airfoil wing concept for use on subsonic aircraft to delay the drag rise and extend range and speed, and contracted for a study of the feasibility of applying this concept to a test aircraft for full-scale flight evaluation.

Aircraft Structures

Tests of a polymer reinforced with glass fibers, which could reduce structural weight for supersonic aircraft, showed that strength tended to decrease as temperature, exposure time, and atmospheric pressure increased. The material was subjected to varying temperatures and pressures for up to 30,000 hours.

Air-Breathing Propulsion

A liquid hydrogen-fueled hypersonic ramjet research engine capable of operating under Mach 8 flight conditions is under contract. The engine will be suitable for flight tests on the X-15 research airplane and should enable investigators to make a realistic assessment of future ground and flight research requirements for hypersonic air-breathing propulsion systems. In the advanced engine component research program, F-106 and F-111 aircraft were obtained on loan from the Department of Defense for use in the flight phase of research into problems associated with aircraft-engine integration and compatibility.

Aircraft Operating Problems

Limited operational and research studies of ways to improve tire-runway traction and control capability on wet surfaces indicated that transverse grooves on the runway surface can prevent loss of traction. Laboratory tests were under way at year's end to determine optimum groove configuration and spacing for use in full-scale tests, and the Wallops Station (Va.) runway was being prepared for full-scale tests with a wide range of aircraft to evaluate the effectiveness of the grooved-runway concept.

The Federal Aviation Administration and airport operators at selected locations about the country, in cooperation with NASA, grooved runways and taxiways with a variety of configurations to provide information on the effects of routine traffic, snow-removal equipment, and other factors on the grooving and on the aircraft. Results of this research will give aircraft users and airport operators a basis for cost-benefit analysis of grooves.

Laboratory experiments for modifying warm fog showed that visibility can be increased significantly by seeding with small amounts of salt crystals of carefully controlled size (about .0003 inches in diameter).

NASA sponsored studies of ignition of aviation fuels in a hazardous environment. Static electricity and lightning-induced arcing were investigated. The latter complements work sponsored by the FAA on lightning strikes to aircraft fuel vent outlets, but the NASA effort carries the research on potential ignition causes further into the fuel system.

In other work on lightning hazards to aircraft, flame propagation in foam layers of various fuels was measured, data were collected on the mechanisms of ignition by static sparks generated in sloshing fuel foams, and information was obtained on the effects of lightning strikes (hole burning) on various aircraft metals.

Aircraft Flight Dynamics

In noise-abatement studies, flight tests of five multi-engine jet transport aircraft in steepened approach profiles indicated that such an approach technique is technically feasible for noise reduction, but that considerably more study is required before steepened approaches can be considered operational.

The research showed that major obstacles are in the information provided the pilot, in the method of flight path control, and in providing steepened-approach profile guidance. Potential improvements in flight path control by means of direct lift control were investigated in ground-based simulators and in flight tests, with the newer control systems producing increased control accuracy.

Aircraft Noise Alleviation

Contracts were made with two firms to study turbofan nacelle modifications for minimizing fan-compressor noise radiation. Operational four-engine jet transports will be modified to explore performance penalties and noise reduction by flight tests of flight-rated hardware.

A long-range aircraft noise-reduction research effort to develop the technology for a Quiet Engine was initiated with new engine cycle studies and analysis of the possibilities of fitting such an engine on current and planned jet transport aircraft. In this program, the engine is in the 20,000-25,000-lb. thrust class, with a bypass ratio between 3 and 8 and a potential noise reduction of about 20 PNdB.

General-Aviation Aircraft

In its program to obtain baseline aerodynamic data necessary to define problem areas of general-aviation-class aircraft requiring further study, NASA purchased a light twin-engine aircraft representative of this class. Full-scale wind-tunnel tests of the aircraft were completed in the Langley 30' x 60' wind tunnel in order to obtain basic aerodynamic and stability data. Flight tests were scheduled to validate and correlate with the wind-tunnel data, and subsequent tests of dynamically scaled models of the aircraft in other tunnels will investigate more hazardous flight regimes.

V/STOL Aircraft

Construction of the Langley Research Center V/STOL transition research tunnel was started in the fall. The tunnel is expected to be operational in the summer of 1969. Unique features include an endless-belt moving-ground plane for ground-effect tests and special test-section walls designed to minimize wall-effects for various types of V/STOL aircraft.

Wind-tunnel studies of lift-fan and other VTOL models potentially applicable to civil and military requirements were continued at Ames and Langley, and the Lewis Research Center initiated an extensive program to improve V/STOL propulsion system concepts--especially the lift fan.

Supersonic Transport

NASA continued to give technical support to the national supersonic transport program in the form of consultation and wind-tunnel tests for the FAA and for the SST contractors. Wind-tunnel studies were initiated for an advanced second-generation domestic SST, and the general-purpose airborne simulator (GPAS) modified commercial airplane was used to simulate XB-70 characteristics for comparisons with actual XB-70 flight-test results to assure its usefulness in SST simulation. After the simulation is validated, the GPAS will be programmed to simulate SST characteristics to define handling qualities and piloting problems that may need further research.

NASA-USAF XB-70 Flight Research Program

On January 17, the XB-70 Number 1 completed the last of nine sonic-boom flights (3 in 1967) to obtain high-priority research data in support of the national supersonic transport program. Two additional flights -- to obtain stability, control, and handling qualities data and to evaluate a new fuel -- were also made in January.

On January 31 it was decided to transfer XB-70 program management, operational control, and funding responsibility from the Air Force to NASA, and to scale down the contractual effort to a $10-million-per-year level, primarily by reducing flight frequency. Formal transfer of the aircraft to NASA took place on March 28.

The first flight of the joint NASA-USAF program under NASA management was made on April 25. The high-priority test objectives for this flight and the subsequent 1967 flights were to obtain additional data concerning dynamic loads; stability, control, and handling qualities; engine-inlet matching; and general aircraft performance

X-15 Research Aircraft

The X-15 airplanes continued to provide basic research data on manned maneuverable flight at hypersonic speeds and to serve as test-beds to carry several advanced technology experiments to the required high-altitude or high-velocity environment. A total of 191 flights had been made by these aircraft before the fatal accident in November. One X-15 and its pilot were lost.

The X-15-2 made one flight with the external tanks and the hypersonic research engine (HRE) installed. The entire airplane, including the external tanks and HRE shape, was coated with ablative material for this flight, the second on which the external propellants were used. A maximum velocity of 4,534 miles per hour was achieved--the highest velocity attained to date in the X-15 program. Shock waves generated by the HRE shape interacted with the boundary layer on the ventral fin on this flight, resulting in damage to the ventral.

The X-15-3 crashed on November 15, following re-entry into the atmosphere after a flight to between 260,000 and 265,000 feet. Maj. Michael J. Adams, USAF, was killed in the accident. The flight was Maj. Adams' seventh in an X-15 aircraft, and the sixty-fifth for the X-15-3. A NASA-USAF Accident Investigation Board was appointed immediately after the accident, to analyze all available data and, if possible, determine the probable cause.

CHEMICAL PROPULSION

Liquid Propulsion Systems

Spacecraft propulsion research efforts emphasized engine components for use with high-energy space-storable propellants, such as the oxygen difluoride-diborane combination. Technology was developed for depositing pyrolytic graphite and carbides, such as hafnium carbide, and thus forming structures whose properties may be controlled. The identification of azides as sensitive chemical intermediates formed by residual propellant from a previous run indicated the need for techniques to prevent explosive engine starts in space.

Tank expulsion bladders and diaphragms were improved to provide the capability for reliable operation after hundreds of days in space; tests were begun to establish the magnitude and effects of stresses caused by folding; and analytical methods were developed for calculating diffusion leakage through minute breaks in a sandwiched permeability barrier.

Experimental testing of space-storable propellants was continued, and improved thrust-chamber performance demonstrated with the FLOX-liquified petroleum gas (LPG) and oxygen difluoride-diborane propellant combinations in the low chamber-pressure operating range. For the LPG fuels, work was started to investigate and demonstrate the limits of regenerative cooling at high chamber pressures over a range of thrust levels.

Solid Motor Program

The third firing of the 260-inch-diameter motor, which was carried out at the contractor's plant in June, generated a peak thrust of over 5.8 million pounds. A motor case, nozzle, and insulation components from previous firings were used, but the motor had a larger nozzle (89-inch throat) and a faster-burning propellant to allow the 50-percent increase in thrust over previous tests. All primary objectives were attained.

Performance was generally as predicted except for indications of erratic propellant burning at about 60 seconds of the planned 70 seconds burning time. Minor propellant breakup occurred, some of it passing through the nozzle and causing shocks which damaged the nozzle exit cone. The breakup was attributed to localized layering and unbonding of the very viscous fuel when it was poured into the motor. Design studies of vehicles utilizing the 260-inch solid motor indicate that it can be combined with the top stage of SATURN V to orbit 95,000 pounds; with the middle stage - 160,000 pounds; and strapped onto the entire SATURN V -- over 700,000 pounds. Uprated SATURN I launch pads can also be adapted to use a single 260-inch booster vehicle.

Studies of small, high-energy solid motors for space propulsion applications showed that the addition of high-energy beryllium to the SURVEYOR decelerator motor fuel could have increased useful payload by 45 percent.

Two firings of such a motor were carried out to prove achievement of the predicted performance level.

Solid Propulsion Technology

Through research at Langley Research Center and the Jet Propulsion Laboratory, including studies of new polymers for propellant binders applicable to solid motors of specific characteristics, advances were made in understanding and controlling solid motor combustion instability. Tests were started on a microwave non-destructive testing technique applicable to a large block of solid propellant within a metal case. When perfected, this method will permit the inspection of large solid motors and other viscoelastic materials, such as aircraft tires, for voids, cracks, fissures, or bond separations.

BIOTECHNOLOGY AND HUMAN RESEARCH

Cardiovascular Research

NASA initiated a comprehensive study of cardiovascular physiology using a systems analysis approach. By using engineering techniques to study the interactions between the subsystems, independent cardiovascular research data can be coordinated, primary control variables can be identified, system response to unusual environments can be predicted, and gaps in knowledge of cardiovascular system functioning can be recognized.

Ames Research Center developed an implantable pressure sensor which measures actual pressures within the chambers of the heart. The unit uses a magnetic latch switch which permits turning the power on and off, thus extending the lifetime of the battery. Ames also studies the elasticity of blood vessels by measuring the speed of a pressure pulse wave as it was propagated through the blood stream.

The present technique requires surgery, but apparently it will be possible to make this measurement on the surface. The ability to thus measure elasticity could be used to obtain an index to the state of deconditioning from weightlessness. The technique may also be useful for diagnosing atherosclerosis.

Respiratory Research

Studies of the mechanisms of oxygen toxicity at Ames Research Center revealed various types of physiological damage in dogs. Eye damage and extreme lung and kidney sensitivity were observed after exposures to 450-mm pressure of pure oxygen for as long as 33 days. Enlargement of the pulmonary arteries was caused by vascular obstructions in the lung from the toxic reaction to oxygen and resulting hypertension, and various histological and ultrastructural changes were caused by oxygen toxicity in rats, rabbits, and dogs at various pressures.

Life Support Systems

A new zero-g capability water electrolysis system to recover oxygen from metabolically produced water in space flight was developed. It incorporated a non-metallic housing to prevent corrosion, improved techniques to separate the liquid and gas, and better sealing and control, and should eliminate electrochemical problems experienced by the first full-scale zero-g capability electrolysis units. Also, biological and chemical standards were drafted for air and for water potability in regenerative systems to be used on long space flights.

Protective Systems

The Ames Research Center developed a new hard space suit with a constant volume joint. The Manned Spacecraft Center used the new joint in combination with features of a soft suit (such as the APOLLO suit) to improve astronaut mobility. With the new suit, kneeling became easier and step height capability was increased from 20 inches to 30 inches.

Handling Qualities

To evaluate man's ability to control and utilize a rocket-propelled maneuvering unit under lunar gravity, tethered flight experiments were conducted on a one-man lunar flying vehicle at the Langley Lunar Landing Research Facility, where the Moon's one-sixth gravity condition was simulated. Test pilots simulated lunar exploration flights in shirtsleeves, in a pressurized APOLLO soft suit, and in the experimental Manned Spacecraft Center hard suit.

Effects of Reduced Gravity on Human Performance

The energy costs for performing physical tasks in the lunar-gravity environment were studied in the one-sixth-gravity simulator and the metabolic expenditure rate was found to be related to the traction reduction which occurs in one-sixth Earth gravity.

In a study of human performance in zero gravity, it was determined that man's capability to perform maintenance and assembly tasks in space is enhanced by properly designed tools, restraint devices, and locomotion aids, and that job tasks must be designed with allowance for the limitations imposed by the reduced gravity environment.

Flight Experiments

The Aerosol Particle Analyzer, which measures dust particles in the cabin atmosphere, and the Orbital Otolith Experiment, which will provide basic physiological information on how the balance mechanism reacts to the zero-g environment, were rescheduled for the first APOLLO Applications experiment mission.

Investigators completed design studies of the life-support and experimentation hardware for an experiment into the effects on a total body system of long-term exposure to zero-g in primates.

While breadboard test models were being assembled, scientists from NASA centers, Department of Defense, National Institutes of Health, and universities carried out research on the problems of diet, confinement, and training, and worked to establish baseline data for the experiment. A new centrifuge experiment study was started to determine the requirements for a man-carrying centrifuge which could be included in APOLLO Applications or a later orbital research program and which would permit flight research with varying levels of acceleration following weightlessness.

SPACE VEHICLE SYSTEMS

Aerothermodynamics

A flight program to determine the deployment, performance, and stability characteristics of parachutes suitable for decelerating a probe into the Martian atmosphere was successfully completed. Vehicles incorporating parachutes ranging from 30 to 85 feet in diameter were launched by large balloons and rockets to high altitudes, where test conditions simulated flight in the Martian atmosphere.

Progress also continued in research on high-performance steerable gliding parachutes for land recovery of manned spacecraft; a drop-test program was initiated which will include large parachute systems at flight conditions representative of a full-sized returning manned spacecraft.

The NASA M-2/F-2 lifting-body research vehicle, which made 15 successful flights between July 12, 1966, and May 2, 1967, incurred extensive damage in a landing accident on May 10. The HL-10 vehicle, which exhibited some deficiences in roll control in its initial flight in December, 1966, underwent additional wind-tunnel tests and analyses and was modified for resumption of flight testing. Re-entry heating research continued with preparation of a SCOUT-launched flight research experiment to determine heating to a body with a turbulent boundary layer and to study boundary layer transition from laminar to turbulent flow at hypersonic speeds.

Structures

A new type of construction for pressure vessels, developed as part of a Lewis Research Center program, consists of a metal tank overwrapped with glass filaments; an optimum level of compression is induced in the metal by appropriate tension in the glass fibers. The experimental models demonstrated increased reliability and substantial weight savings for high-pressure systems over temperatures ranging from 75°F down to -423°F.

Environmental Factors

The three PEGASUS spacecraft, launched in 1965 to count meteoroid penetrations in metallic skins, successfully completed their primary mission, and their operation was extended to provide information on the reliability of the spacecraft electronic systems. All systems continued to operate satisfactorily during a year of the extended lifetime.

An artificial meteor which was sent back into the Earth's atmosphere at a meteoritic velocity of 56,000 feet per second gave data for use in analyzing natural meteor observations. From research on laboratory meteoroid simulation, a device was developed that accelerated a meteoroid-like particle to 42,000 feet per second. When fully developed, this device will make it possible to improve research on spacecraft structures to withstand meteoroid penetrations.

ELECTRONICS AND CONTROL

Stabilized Inertial Test Platform

Electronics Research Center research on laboratory evaluation equipment for inertial navigation sensors, celestial trackers, and fine-pointing sensors being developed for aeronautics and space applications resulted in fabrication and testing of a single-axis test base which can be isolated from small motions of the laboratory floor.

The base uses precision-level sensors for tilt isolation, and an inertial guidance-quality gyroscope combined with conventional devices for vibration isolation. Experimental testing proved the feasibility of the technique, and it will be incorporated into the design of a full-scale prototype platform for further evaluation.

Star Tracker Calibration

Goddard Space Flight Center developed a calibration methodology and associated hardware for star trackers. The procedure is based on the use of a "standard star" source at the National Bureau of Standards as a reference and a computer program developed at the Center. The accuracy of this new calibration technique, approximately 10 to 15 percent, was verified with flight data from the AEROBEE Sounding Rocket program, and the method was put into use as a standard procedure for star trackers.

Control Systems

Spacecraft and aircraft flight-control systems research activities included operation of a control-moment gyro test stand for supplementary testing of the APOLLO Telescope Mount project and other advanced systems; operation of the satellite attitude-control facility at the Ames Research Center for Advanced ORBITING ASTRONOMICAL OBSERVATORY project development; demonstration of an advanced TV display with a 75 percent improvement in character recognition accuracy without increased bandwidth; successful completion of flight tests of an indirect viewing optical device for improved pilot visibility on lifting body re-entry vehicles; and development of a low-inertia, low-noise variable field tachometer and motor, which may have industrial applications.

Supersonic Aircraft Integrated Avionics

A program was initiated to develop the technology for an integrated avionics system (communications, navigation, data processing, flight control, and instrumentation functions) for commercial supersonic aircraft of the late 1970's. The Electronics Research Center, with support from other NASA centers, began systems research, component research, and subsystem development. A target date of 1972 was set for making the documented technology available to industry.

Project RAM

This is a research program of ballistic flights to investigate techniques which will minimize or eliminate the loss of communication and tracking signals during atmospheric entry. In October, RAM (Radio Attenuation Measurements) C-A was successfully flown in the medium-re-entry velocity regime (15,833 - 18,020 mph) to supplement previous tests at re-entry velocities of 18,000 feet per second.

Results indicated that injection of water into the plasma sheath and use of higher frequencies (X-band in this test) for decreasing the re-entry blackout period are still effective at these higher speeds.

Lasers

Equipment was developed which uses pulsed laser beams in a manner similar to that of conventional radar to measure the range of near-Earth satellites more accurately. A pulsed ruby laser with a repetition rate of two per second and power output of three joules was used as the transmitter and retro reflectors were installed in the satellites to augment the returned signal. Accuracies of plus/minus 1.5 meters were routinely obtained.

Tests proved the feasibility of the concept of using lasers to provide real-time video pictures from Mars distances with antennas of reasonable size. Techniques for acquiring narrow laser beams and for pointing receiving telescopes with an accuracy of one tenth of an arc-second were demonstrated using helium-neon lasers.

Coding Techniques

A technique was developed for coding communication signals so that they can be more accurately detected in the presence of noise at maximum ranges. The new development--convolutional coding with sequential decoding--which gives the encoded signal a known character or rhythm making it more easily separated from the noise background, may double the range capability of a given system, permit the use of half the spacecraft power, or enable twice as much information to be sent in a given time. It will be installed in PIONEER spacecraft to confirm in space the ground-test results.

Associative Memories

Studies at the Electronics Research Center showed that new computer memories based on associative search concepts can reduce the data-transmission load of spacecraft transmitters by simultaneously monitoring the output of many different instruments and selecting data only from those which exhibit the "most significant" activity. Such "associative" memories, which process and select data according to content rather than storage location, as do current digital computers, reduce the number of operations required to locate a specific element of data by a factor of 600 or more, thus using the available bandwidth more efficiently.

Ablation Measuring

Langley Research Center developed an improved method for continuous measurement of the ablation of materials used to absorb energy produced when spacecraft enter planetary atmospheres at high speeds. Radioisotopes were embedded throughout the ablation material, and the change in radiation was measured during the ablation process. Laboratory test results agreed with actual specimen thickness measurements to within .04 inch when ablators of one-inch original thickness were heated by acetylene oxygen torch.

Mass Measurement at Zero G

A method of weighing biological experiments under zero-g was developed by the Ames Research Center. The technique substituted an oscillating spring-mass system for conventional spring scales or balances which depend on the effect of a constant gravitational force. Since the oscillatory frequency of a spring-mass system depends on the total mass, any variation of the mass will result in a detectable change in frequency. A device based on this principle was built to measure specimens from 20 mg up to 50 g within an accuracy of 1 percent.

Hypersonic Force Measurements

An electrical null balance system was developed to measure aerodynamic forces on the models in hypersonic wind tunnels in three directions. The system measures the currents in field coils required to maintain model balance under applied loads and is calibrated to translate these currents into the effective aerodynamic forces.

SPACE POWER AND ELECTRIC PROPULSION

Nuclear power generation, solar and chemical power research, and electric thrusters continued to receive major R&D emphasis, with significant results.

Nuclear Power Generation

In the 35-KWe SNAP-8 development project, progress was accelerated, with more test hours on major components being accumulated during 1967 than in all previous years combined. All major components except the boiler and turbine have been subjected to 2,500 hours or more of endurance testing, with the lubricant/coolant pump passing the 10,000-hour mark.

Testing was initiated on a new turbine and new boiler, each modified to correct previously identified life-limiting deficiencies. The first power-conversion system, which is in a breadboarded configuration, was continuing to supply system technology data.

a. Work on the SNAP-19 isotope generator for the NIMBUS B spacecraft entered the final stages.

b. The SNAP-27 generator reached the qualification test stage as a power source for the APOLLO Lunar Surface Experiments Package (ALSEP).

c. In the advanced nuclear electric power program emphasis continued on three energy-conversion concepts: the potassium Rankine and Brayton turbogenerator systems, and the thermionic direct-conversion system.

d. Experiments with uranium oxide, being conducted under contract, are leading to fuel design techniques for venting fission gas without loss of fuel. A thermionic reactor analog was developed at the Jet Propulsion Laboratory for rapid analysis of reactor stability and control.

e. Experiments on electrical arcing through cracked insulators in the presence of cesium vapor showed the importance of preventing exposure of the insulators to cesium vapor.

f. The Brayton-cycle turbogenerator program continued to develop high-performance component technology for the 2-10 KWe power range. During the year emphasis was placed on a 5.5-KW compact rotating unit in which the turbine, compressor, and alternator are arranged on a single shaft supported on gas bearings. Individual cold-flow test components for this unit were fabricated. In addition, approximately 20 hours of performance mapping were completed on a research turbo-compressor operating with a 1,500°F turbine inlet temperature.

Solar and Chemical Power

Step one of a planned three-step program to achieve technology readiness of light-weight folding photovoltaic solar cell arrays up to 50-KW capacity was completed in November, and step two was initiated. For interplanetary spacecraft, which are in the sunlight almost continuously, a 5,000-square-foot solar cell array would be needed to generate 50 KW of electric power at 1 A. U. (the Earth's mean distance from the Sun).

A 50-square-foot model of a new rollup packaging concept for compact stowage of large solar cell arrays during launch was completed in March. Thousands of small, individual solar cells would be attached to a flexible plastic substrate such as epoxy fiber glass. The cells and substrate would be rolled up on a spool together with collapsible booms. The plastic substrate and booms would be deployed in space to provide the necessary array area. The collapsible booms form a relatively rigid shape when deployed and give the needed stiffness for holding the plastic substrate and solar cells in a flat plane broadside to the Sun.

Research on electrical circuits, components, and techniques for conditioning, distributing, and controlling electric power continued to be directed toward greater reliability and higher power levels. Techniques were developed for parallel operation of multiple low-input voltage converters and for electrical isolation of individual converters should an in-flight failure occur.

Conditioning several kilowatts of electrical power in single converter modules, at efficiencies of about 95 percent, was demonstrated. However, further research is required to verify that present laboratory circuits are adequate for spacecraft applications and to explore the possibility of scaling to higher power levels (possibly 40 KW in a single module).

An important advancement was the laboratory-demonstrated single-control module which can be used with a wide variety of pulse-modulated power-conditioning circuits. In addition to providing reliability and cost advantages if standardized, the new circuit has demonstrated an accuracy and stability substantially exceeding the capabilities of existing voltage reference components.

Until recently the lightweight silver-zinc battery has been limited to approximately room-temperature operation. In addition, such a battery can withstand relatively few recharges. A new type of inorganic separator material--to keep the electrodes from short-circuiting--now permits hundreds of charge-discharge cycles at boiling water temperature and over 2,500 cycles at room temperature. The same separator material should also make these batteries more useful for civilian applications.

Electric Thruster Systems

During the year, the major emphasis in electric propulsion was on preparing the second flight in the Space Electric Rocket Test (SERT) program, on continuing the evaluation of solar-powered electric propulsion systems for advanced space probe applications, and on developing small thruster systems intended for auxiliary propulsion.

The SERT flight, scheduled for launch in 1969, has the major objective of verifying in space the long-duration ion thruster performance previously demonstrated in ground tests. During the past year the configuration was defined, major contracts were let, and the basis of the experiment package was developed.

Progress was also made in the systems technology required for using such engines as the prime propulsion of spacecraft on deep-space missions. This work has thus far continued to indicate that such systems using power from solar arrays appear feasible and have merit.

THE NUCLEAR ROCKET PROGRAM

The joint NASA/AEC nuclear rocket program continued to stress the development of graphite reactor and engine system technology. Through previous efforts, reactors have been developed and operated at conditions which would produce a specific impulse of 800 seconds in a flight engine. Reactors have been cycled and recycled through startup, full power and shutdown. Three separate reactors have been operated for test durations of 30 minutes at powers above 1,000 megawatts. (One of these, the PHOEBUS-1B, was operated in February of this year for 30 minutes at power levels approaching 1,500 megawatts).

The NRX-A6 nuclear rocket reactor was successfully tested at full power of about 1,100 megawatts for approximately 60 minutes--twice as long as any previous rocket reactor had been operated at its rated power.

Ground Experimental Engine Investigations

The nuclear rocket program moved well into the final phase of work aimed at the development of engine system technology. The remaining objectives are to be achieved through ground experimental engine (XE) investigations in Engine Test Stand No. 1 (ETS-1). These investigations will for the first time combine all of the components of a nuclear rocket engine in a flight configuration for testing under simulated altitude conditions.

At the Nuclear Rocket Development Station (NRDS) in Jackass Flats, Nevada, the NERVA development team was in the final stages of preparation for conducting cold-flow experiments on an XE engine (XECF) in ETS-1.

These tests should verify that ETS-1 is ready for hot-engine testing, investigate the startup of the XE engine in ETS-1 under simulated altitude conditions, check engine/test stand operating procedures not previously demonstrated, and investigate engine malfunctions under simulated conditions. The XECF engine experiments will be followed in 1968 by the first tests on a "hot" XE engine. Assembly of this engine was nearing completion at the close of the year.

Non-Nuclear Component Development Activities

Since the joint NASA/AEC nuclear rocket program was reoriented in 1963 to a ground experimental engine development activity, ten successive, successful tests of reactors have been conducted. Each was the culmination of many concerted component development activities. Each test also served as a building block to advance the state of the technology and to prepare the way for the next series of experiments.

The Los Alamos Scientific Laboratory began conducting experiments on a scaled up version of the 1,000 to 1,500-megawatt KIWI-sized PHOEBUS 1/NRX reactor called the PHOEBUS 2. Before these experiments could be initiated, a major effort was undertaken to provide a large-diameter nozzle to accommodate the higher PHOEBUS 2 operating temperatures and stresses. Also a new facility feed system was designed, developed, and installed at Test Cell C to provide the increased flow of liquid hydrogen required.

During 1967, three PHOEBUS 2 nozzles were fabricated. In a 75-second chemical test firing, the contractor showed that the nozzle could withstand the heat fluxes and thermal cycling of a full-power PHOEBUS 2 reactor test.

The facility feed system selected for use in Test Cell C was a twin turbopump assembly called the NFS-3b. The basic unit of the NFS-3b is the Mk 25 turbopump. Two of these units are connected in a parallel system to provide the liquid-hydrogen flow rate required (285 lbs/sec.). A unique feature of the system, however, is that it can be operated in what is called the "single-mode" (one turbopump operating) to provide the lower flow-rates required to conduct the PHOEBUS 1/NRX KIWI-sized reactor experiments.

Tests run this year on the NFS-3b confirmed the design analyses. System performance was measured to 34,000 rpm in both the single and dual modes. In addition, a single turbopump which had been operated for approximately 30 minutes at 34,000 rpm was run again at 36,000 rpm to demonstrate its ability to operate at overspeed conditions. The performance of the system was smooth and stable at this speed.

TRACKING AND DATA ACQUISITION

Support of NASA missions, as well as missions of other agencies and governments, through the facilities and resources under Tracking and Data Acquisition Program management, continued successfully. While the operational service continued, the facilities and equipment were being modified and implemented to support future programs and missions.

Manned Space Flight Network

During 1967, a program was essentially completed for augmenting the Manned Space Flight Network for support of APOLLO. This consisted of the upgrading of existing facilities, which had successfully supported both MERCURY and GEMINI, and the addition of APOLLO instrumentation ships, APOLLO/Range Instrumentation Aircraft (A/RIA), and new land stations.

The total network for support of APOLLO lunar missions consists of 14 land stations, 5 instrumentation ships, and 8 instrumentation aircraft. All of the land stations are now fully operational. The ships and aircraft are in various test phases but will become operational during the first half of calendar year 1968.

Despite the delay in the APOLLO schedule, during most of the year the network continued to play an active role in support of other NASA flight missions. Selected network stations, such as Bermuda and Carnarvon, Australia, provided support to many unmanned missions, including SURVEYOR, LUNAR ORBITER, and the ORBITING GEOPHYSICAL OBSERVATORY. In addition, the network supported the TITAN IIIC vehicle development flights and other Department of Defense programs.

The LUNAR ORBITER was used successfully in simulating APOLLO lunar mission tracking operations as a means of qualifying the stations and verifying APOLLO navigational techniques. This important operation was performed with LUNAR ORBITER spacecraft after completion of their primary lunar surface photograph missions.

On November 9, the network participated in the highly successful APOLLO 4 mission.

Satellite Network

The Satellite Network continued to carry a very heavy workload in terms of total satellites supported, with an average of 38 to 40 satellites being supported by the network on a daily basis.

NASA's support of international programs is carried out largely through the activities of this network. The SAN MARCO, ESRO, ARIEL and WRESAT projects were all supported by the Space Tracking and Data Acquisition Network (STADAN) with the data from experiments being processed in a form that can be given to the individual experimenters for reduction and analysis of scientific results.

Deep Space Network

The lunar and planetary programs, which included a number of successful longlife missions over the past few years, placed a heavy workload on the Deep Space Network facilities. Continuous support of MARINER, LUNAR ORBITER, and

PIONEER missions, as well as the shorter SURVEYOR missions, kept the network operating on an exceptionally busy schedule. The clarity and definition of photographs, transmitted from the LUNAR ORBITER and SURVEYOR spacecraft through the network facilities, also continued to highlight the successful support.

The 210-foot-diameter advanced antenna system, which became operational in 1966 at Goldstone, California, has performed in an excellent manner and fulfilled all planned design objectives of the system.

Network Communications

The NASA Communications Network (NASCOM) is the interconnecting link between the network stations and control centers. The NASCOM continued during the period its successful record in meeting the operational communications requirements of NASA and other agencies.

With the launch of three successful commercial communications satellites (INTELSAT) this year, an important link was added to the communications system. These satellites over the Pacific Ocean and over the Atlantic Ocean are required to provide the necessary communications reliability between the APOLLO mission control center, the instrumentation ships at sea, and the land stations at Canary Island; Ascension Island; and Carnarvon, Australia.

UNIVERSITY PROGRAMS

NASA's university program looks to universities to supply expertise and competence essential to the space effort. In turn, the program feeds back knowledge gained from space exploration into space and other applications to help the United States maintain its leadership in aeronautics and astronautics.

During this year, about 1,400 grants and contracts--valued at almost $110 million--were in effect at 200 U. S. colleges and universities. Most of this university support, about $80 million dollars, was financed and directed by project offices and research centers with immediate requirements for the development and application of new knowledge. NASA's Sustaining University Program supplements and balances the project research in addition to supporting university training activities and the construction of research facilities.

Under the predoctoral training program, 797 new students began their graduate training at 152 colleges and universities, including at least one institution in each state, in September, 1967. Of the 900 doctorates awarded since the program began, nearly 60 percent of the recipients remained in the universities, 30 percent took positions with industrial firms, and 10 percent entered Government service either as civilians or as members of one of the military services. In another part of the sustaining university program, about 250 university faculty members participated in nine summer fellowship programs in research or systems engineering design. Also, multidisciplinary research grants were continued at 50 universities, and the 940 investigators working under these grants published about 750 scientific papers.

Seven research laboratories on university campuses were dedicated, bringing the total completed to 25 since the program began. These laboratories comprise nearly 900,000 square feet and accommodate some 3,000 engineers, scientists and graduate students working on aeronautical and space-related problems. One grant was awarded for a new facility.

INTERNATIONAL AFFAIRS

International cooperation in joint projects and operations support activities continued to expand in 1967.

Agreements were concluded with the space commissions of Brazil and Mexico to undertake joint research in the techniques of remote sensing for Earth resources surveys. Both ground-based and airborne instrumentation will be tested to develop possible capabilities for the eventual survey of resources by spacecraft.

NASA and the Indian Committee for Space Research agreed to undertake a joint study of the possible use of an experimental communications satellite for instructional television purposes in India.

During the year, 29 scientists from the United Kingdom, West Germany, Japan, Canada, Switzerland, and Finland were selected to participate as principal investigators in the lunar surface sample program. These scientists will join their U. S. colleagues in studying and analyzing the lunar surface material to be brought back to Earth by the APOLLO astronauts.

Two cooperative satellites, the Italian SAN MARCO II and the British ARIEL III, were successfully launched on April 20 and May 5, respectively.

The SAN MARCO II involved the first use of a unique ocean platform launch complex built and equipped by the Italians. The launching occurred on the equator off the east coast of Africa. The satellite continued the air density measurements made by earlier SAN MARCO spacecraft, using the Italian-developed drag-balance technique for the first direct measurements of local density.

ARIEL III continued the work of British scientists in charged particle studies and measurements of low-frequency radiation in space.

The attempted launching on May 29 of the ESRO II satellite built by the European Space Research Organization was not successful because the SCOUT booster failed. This was the first of nine international satellites to fail to achieve orbit. A backup spacecraft is to be launched in early 1968.

Cooperative sounding rocket programs continued with ten foreign countries. These programs concern astronomical investigations and studies of the upper atmosphere and ionosphere, using sodium-vapor and barium-cloud techniques, grenades, X-ray telescopes, magnetometers and charged-particle detectors. The first comparative sounding rocket system tests to use foreign-developed vehicles (Japanese MT-135 rocket) were conducted from Wallops Island, Virginia.

Cooperative work with Brazil was expanded to provide a capability to launch the large JAVELIN sounding rocket from the range at Natal, Brazil. In June, two JAVELIN launchings were successfully undertaken in a tripartite program (U. S., Germany and Brazil). The rockets carried experiments designed to test instrumentation for a projected West German research satellite to be launched by NASA.

The successful Inter-American Experimental Meteorological Rocket Network (EXAMETNET) program with Argentina and Brazil continued at an active pace.

Small meteorological rockets launched in those two countries were coordinated with NASA launchings at Wallops Island.

Cooperation in aeronautical research continued through an agreement with the U. K. Ministry of Technology providing for a joint research program on the British-developed Hunting 127 jet flap aircraft.

The telemetry/command station constructed by the European Space Research Organization near Fairbanks, Alaska, achieved operational capability in the fall.

Argentina, Australia, Chad, Chile, Ecuador, Mexico, New Zealand, the Philippines, Senegal, South Africa, Surinam, and the United Kingdom agreed to the stationing of temporary geodetic satellite observation camera teams on their territories as part of the National Geodetic Satellite Program.

INDUSTRY AFFAIRS

NASA's industry affairs stressed incentive contracting, cost reduction, improved labor relations, reliability and quality assurance, and increased use of DOD contract administration.

Incentive Contracting

NASA's procurement management research programs are designed to develop the most effective incentive contracting procedures. The agency's studies of extra-contractual influences and profit motivating factors are expected to have a significant effect on future incentive policies.

The volume of incentives under administration increased more than twenty-five percent during the last year. NASA entered Fiscal Year 1968 with 266 incentive contracts amounting to $6.7 billion. While the agency encouraged the continuing growth of incentive contracting, it emphasized that this is only one aspect of the overall procurement program. Along this line, certain incentive contracts were converted to Cost-Plus-Fixed-Fee when the limits of contract definition under changed conditions showed such conversion to be most appropriate.

NASA coordinated its efforts with other Government Agencies in developing Cost-Plus-Award-Fee (CPAF) policies and procedures. The CPAF contract fits in the spectrum of available contracts between the Cost-Plus-Fixed-Fee and the formula incentive types, with the potential fee based on subjective evaluations of actual performance. This relatively new contract type provides benefits for both the Government and the contractor.

Cost Reduction

The NASA internal cost reduction program resulted in measurable savings of $180,000,000. The Agency's major contractors, voluntarily participating in the contractor program, achieved savings of $220,000,000. For the four years the Program has been in operation, NASA has reported total savings of more than $1,400,000,000.

Labor Relations

The labor relations program emphasized pre-planning actions to prevent labor problems during the procurement process. Total man-days lost because of work stoppage at all NASA Centers decreased by about 85 percent during 1967. Only 3,317 man-days were lost in 1967 as compared to a loss of 39,088 man-days in 1966.

The Kennedy Space Center experienced a significant improvement in labor stability during 1967, with 216 man-days lost from work stoppage as compared to 13,487 lost during 1966. This was accomplished even though there was an increase in the total man-days worked at that Center.

Reliability and Quality Assurance

In another area of effort, the Reliability and Quality Assurance Office expanded its evaluations of field installations to include all reliability and quality assurance activities, not only those associated with procurement. Five field installations were evaluated by the end of 1967. Included in these evaluations were several plant offices and test sites associated with manned space flight.

Increased Use of DOD Contract Administration

NASA increased its use of DOD contract administration activities and continued working closely with DOD management to make sure that agency programs received appropriate attention.

NASA expanded its participation with DOD in the Contractor Performance Evaluation Program, with 18 major NASA contracts under evaluation. The agency was also working with DOD in refining and applying contractor evaluation systems.

Property Management

Property administration was emphasized during the past year under the President's Program for Improved Supply and Property Management. Following completion of the GEMINI program, $342 million worth of property was reassigned to NASA installations or to other Government agencies for reuse.

TECHNOLOGY UTILIZATION

NASA continued increasing its activities to make the technical results of its research and development program available to potential users in non-aerospace fields.

Two new experimental Regional Dissemination Centers (RDC) were opened in 1967, one in New England and the other in Southern California. These two Centers enrolled 46 industrial firms as clients during their first 10 months.

Three Biomedical Application Teams form a direct link between aerospace scientists and technicians and biomedical researchers at more than a dozen medical schools and research institutes around the country. In addition, the Social and Rehabilitation Service of the Department of Health, Education and Welfare are gaining direct and helpful access to aerospace technology via the NASA biomedical application program.

NASA and the Small Business Administration cooperated in special programs to encourage industrial development in the small-business community by capitalizing on available aerospace technology. The two agencies conducted three conferences on the accessibility of technical information to this sector of the economy. The Atomic Energy Commission, the Department of Commerce Office of State Technical Services, and the Smithsonian Science Information Exchange contributed to the presentations.

The NASA Office of Technology Utilization and the SBA also pursued a one-year experimental program to introduce small businesses to services offered by the NASA-supported Regional Dissemination Centers. Under this program, a number of firms were selected by the SBA to be assisted by the Centers in seeking out and using externally generated knowledge.

The NASA-established Computer Software Management and Information Center in Georgia identifies technological advances in computer programs developed by and for NASA and makes them available for use by private industry. Through this Center NASA contributes directly to the national industrial effort by offering private industry the opportunity both to avoid duplication and to accelerate the lengthy and costly task of developing computer programs. The Center is designed to be self-supporting on the basis of fees received for programs distributed.

Under a cooperative program with NASA, the Atomic Energy Commission's Sandia Laboratories began reporting innovations derived from their research endeavors. These reports will be published and disseminated as AEC-NASA Tech Briefs. The AEC's Argonne National Laboratory embarked on a similar program in 1966 which has resulted in 100 Tech Briefs. The number of Tech Briefs stemming from NASA's program since it began in 1964 reached a total of approximately 2,000 during 1967.

The Bureau of Reclamation Office of Atmospheric Water Resources entered into an interagency agreement with NASA to apply aerospace technology to its weather modification program.

Scientific and technical information compiled, stored, retrieved, and disseminated by the NASA Scientific and Technical Information Program for the benefit of Government, university, and industrial users increased substantially in all categories.

NASA continued initial testing of RECON--a remote-console, direct-access method for retrieval of information from large computerized storage banks. RECON could be extremely valuable to working scientists and engineers who need scientific references immediately.

During the latter part of 1967, the Thesaurus project was completed. Over the years, NASA scientists have developed a special vocabulary of the words and terms applicable to aerospace interests. NASA put that vocabulary into the form of a Thesaurus--a carefully structured set of definitions and relationships. It will serve as a master indexing authority.

RELATIONSHIPS WITH OTHER AGENCIES

NASA continued to work closely with other Government agencies having research, development, and application interests in space and aeronautics. Among these are the Department of Defense, the Department of Transportation, Atomic Energy

Commission, Department of Commerce, Department of Agriculture, and Department of the Interior.

The program for the exchange of personnel between NASA and the DOD continued during 1967. As of December 31, 323 military personnel were on detail to NASA. Of these, 189 were from the Air Force, 99 from the Army, 32 from the Navy, and 3 from the Marine Corps. At that time, 13 NASA employees were assigned to organizations of the DOD.

Aside from the over-all coordinating role of the National Aeronautics and Space Council, the principal formal mechanism for coordination between NASA and DOD was the Aeronautics and Astronautics Coordinating Board (AACB) and its six specialized panels. Through the AACB activities, the two agencies began a comprehensive review of existing aerospace test facilities and anticipated future needs; coordinated their respective space science programs; coordinated their proposed FY 1968 facilities budgets to eliminate unwarranted duplication; and completed a joint study concerning the economic aspects of reusable launch vehicles.

The Board also helped establish procedures and guidelines for both agencies to follow in using secondary payload space on space launch missions. Five flight projects were introduced for coordination under these procedures.

NASA and DOD agreed to transfer management responsibility for the XB-70 Flight Research Program from the Air Force to NASA; on procedures for transferring Air Force Flight and Engine data on the F-12/SR-71 supersonic aircraft to NASA for use in the supersonic transport supporting research program; and on arrangements for DOD to support and eventually to operate the NASA satellite tracking facilities on Grand Bahama Island.

NASA and DOD continued to provide logistical support for each other's programs. In addition to the normal exchange services, the following were noteworthy: DOD tracking and recovery support for NASA's BIOSATELLITE I; DOD flight training of NASA astronauts and research pilots; NASA support of the MOL program; and NASA support of the DOD wind-tunnel testing program.

Joint NASA-DOD reviews and studies were conducted on the following: R&D programs related to cryogenic rocket engines; satellite systems combining communication, air traffic control, surveillance, and navigation; space flight emergency and rescue systems; and reduction of external aircraft noise.

NASA and the Smithsonian Institution developed procedures concerning the custody and display of NASA historical artifacts.

NASA and the Department of Transportation reached an agreement concerning principles for NASA's participation in the research, development, and testing work associated with high-speed ground transportation.

DEPARTMENT OF DEFENSE

CHAPTER IV

INTRODUCTION

In 1967 the Department of Defense space and aeronautical activity was highlighted by two actions: (1) Three TITAN IIIC boosters successfully placed 19 payloads into high orbits, some beyond synchronous. (2) The manufacture and assembly of the world's largest aircraft, the C5A, continued on schedule.

SPACE DEVELOPMENT ACTIVITIES

MANNED ORBITING LABORATORY

The MANNED ORBITING LABORATORY (MOL) progressed into the Engineering Development Phase early in 1967 and a program plan was developed to provide for the launch of a two-man crew aboard the spacecraft at the earliest possible date.

MOL crews will remain in orbit for 30 days conducting defense-oriented experiments involving very complex equipment. Manned space flight experience in the MERCURY and GEMINI programs indicates that both the development and usefulness of this equipment will be enhanced by putting a human operator/experimenter in space along with it. This approach will realize the program objectives of advancing both manned and unmanned space technology and ascertaining the full extent of man's utility in space.

The MOL crews will be launched into orbit inside a GEMINI B spacecraft by an uprated TITAN III booster, designated TITAN IIIM. In orbit the pilots will transfer into the laboratory, which is designed to allow them to work in a "shirt-sleeve" environment, unencumbered by space suits. For return to Earth, they will go back into the GEMINI B, detach it from the laboratory, and re-enter the atmosphere for an ocean landing and recovery.

Development of all of the major components of the MOL system was initiated and progressed on schedule during the past year. The first-stage engine of the TITAN IIIM, employing a new nozzle, was successfully static-tested. Mockup and structural test assemblies of the laboratory and experiment modules were completed and the procurement of system components was begun. Design of the launch complex at Vandenberg AFB, Calif., was completed and construction initiated.

Four more Aerospace Research Pilots were assigned to the MOL flight crew, increasing the total number in training to sixteen. In addition to their flight training and engineering and test operations duties, crew members completed courses in jungle and water survival.

Advance development and fabrication of space suits for the MOL flight crew began during this period. Special design features of the modified GEMINI-style pressure suits will include an extravehicular capability for emergencies, more mobile joints, a self-sealing zipper for unassisted donning and removal, and a bubble helmet for unrestricted visibility.

NASA and DOD continued close coordination and cooperation to insure the exchange of technology, hardware and experience throughout the life of both the APOLLO and MOL programs.

TITAN III Space Booster

The TITAN III Research and Development Program continued in the flight-test phase, with three launches carrying important military payloads into orbit throughout the year. The first of these occurred last January, when eight additional Initial Defense Communication Satellites were placed in a near-synchronous orbit of 18,200 nautical miles. This brought the total of communication satellites put into orbit by the TITAN IIIC to fifteen. In April, a pair of nuclear detection satellites were successfully boosted into an orbit of approximately 60,000 miles. The third flight of the TITAN IIIC took place in July and carried an assortment of six experimental payloads, including three additional Defense Communication Satellites.

Because of its demonstrated reliability and capability, the TITAN IIIC was ordered into production this summer to provide the space boosters for high-priority payloads over the next three years.

Development work continued on the TITAN IIIM, which will be used to launch the MANNED ORBITING LABORATORY (MOL). Launches of the TITAN IIIB also occurred during the year and development was initiated on a TITAN IIID configuration to provide a polar-orbit capability for heavier unmanned payloads.

DOD Communication Satellite Program

The DOD Satellite Communication Programs are divided into two broad categories (Long Distance Point-to-Point and Tactical Systems) supplemented by Supporting Research and Technology.

Long Distance Point-to-Point System

This system is to satisfy those unique and vital national security satellite communications needs which cannot be met by commercial means. Efforts to satisfy this mission can be classified into four areas: SYNCOM, Initial Defense Communications Satellite Project (IDCSP), Operational Defense Satellite Communications System (DSCS), and International Cooperative Efforts.

SYNCOM--The SYNCOM II and III satellites, developed and orbited by NASA, are used with DOD terminals in the Pacific area for passing operational traffic. The SYNCOM system was converted from R&D to an operational system in July, 1966, and is currently being employed in Southeast Asia to provide circuits between ground terminals there and in Hawaii and the Philippines. A shipboard terminal installed on the USS ANNAPOLIS is also being used in this system.

Initial Defense Communications Satellite Project (IDCSP)--The IDCSP provides the initial operational satellite communications capability to satisfy critical requirements of the DOD and other Government agencies. In 1967, the space subsystem was expanded to a total of 17 operational satellites with successful launches in January and July, utilizing TITAN IIIC R&D boosters.

The ground environment of the IDCSP has progressed with equal success. The former system of ground terminals on the east and west coasts of the United States and in Germany, Hawaii and the Philippines was expanded with additional terminals deployed to South Vietnam, Guam, Okinawa, Ethiopia and Hawaii. Recently developed air-transportable and highly mobile, lightweight terminals were deployed to Guam and Australia, and in Colorado and Alaska. Each of these terminals, which can be set up for operation with a six-man crew within an hour, provides a satellite communications facility making possible reliable and flexible communications for command and control for special military missions and for use in underdeveloped areas of the world. The Navy now has shipboard terminals installed in the USS PROVIDENCE, flagship of the Seventh Fleet; USS OKLAHOMA CITY, flagship of the First Fleet; USS WRIGHT; and USS ARLINGTON. In the near future, terminals will also be installed in attack aircraft carriers.

Defense Satellite Communications System (DSCS)--During 1967, the DOD continued planning and preparation for the development and acquisition of an advanced system which will take full advantage of our experience with the SYNCOM and IDSCP systems and current technology.

International Cooperative Efforts--A Memorandum of Understanding was concluded this year with the United Kingdom whereby the space segment of the IDCSP will be augmented with two synchronous satellites to provide operational defense communications. This program, which is entirely financed by the United Kingdom, will provide a first launch in 1968. To demonstrate the interoperability between British and U.S. satellite communications equipment, a Navy shipboard terminal in San Diego successfully communicated with a British shipboard terminal located in Portsdown, England. A similar program was proposed to NATO in September, 1966; in late August of this year, NATO indicated its desire to procure two UK-type satellites. These will be procured and launched in the U.S. by the Air Force.

Tactical Satellite Communications Program

The Tactical Satellite Communications Program made significant progress during 1967. The program consists of early experiments with two Massachusetts Institute of Technology Lincoln Laboratory satellites, followed by more extensive tests with a larger, more complicated satellite. These satellites will provide a means of exploring the technical, operational, and economic feasibility of using repeaters in space to satisfy certain critical tactical communication needs.

The first of the Lincoln Laboratory satellites was successfully orbited on July 1, 1967, and is providing valuable data. Experimental terminals installed in operational vehicles (airplanes, ships, and trucks) are communicating through the satellite and many new communication techniques are being tested. Army vehicular terminals established voice communication with various types of experimental terminals, some of which were at distances of over 4,000 nautical miles. The Navy has successfully communicated through the satellite with terminals installed in a surface ship, submarine, and aircraft. In a related development, an Air Force helicopter in the USA successfully established two-way voice contact with a NASA station in Australia, utilizing NASA's ATS-1 VHF communications satellite repeater.

The U.S. and selected NATO countries are now conducting joint tests using the Lincoln satellite. A second Lincoln satellite for the TacSatCom program is under construction and will be launched in 1968.

Spaceborne Nuclear Detection (VELA)

The objective of the VELA Satellite Program is to develop a satellite capability to detect nuclear explosions which may occur from the Earth's surface to deep space. It is a joint research and development program of the DOD (USAF) and the Atomic Energy Commission.

Two new VELA satellites were successfully launched in April, 1967, by a research and development TITAN IIIC into 60,000-n.m. circular orbits. They joined six other VELA satellites launched in pairs in 1963, 1964 and 1965. The new satellites are stabilized with a gas-jet attitude-control system to keep their spin axes pointed at the center of the Earth. The most important new techniques being investigated are optical and electromagnetic pulse detectors for observing the fireball and radio pulses from nuclear weapons tested in the atmosphere.

All of the satellites are providing valuable information on the natural radiation background in space and the operation of nuclear radiation detectors in a space environment. The radiation background data are supplied to NASA, ESSA and DOD agencies for warnings during manned orbital flights and development of solar-storm forecasting techniques.

Space Object Identification

During 1967 the Air Force and the Advanced Research Projects Agency (ARPA) continued to cooperate in a research program to determine the most feasible methods of identifying the physical characteristics of non-cooperating objects in Earth orbit through observations by ground-based radar and photo-optical devices. Techniques developed will not only be used to obtain diagnostic information on our own satellites in orbit, but also will serve as a prime source of technology for improvement of the Space Surveillance and Detection Tracking System (SPADATS). Most ARPA research in this area has been transferred to Air Force management.

Geodetic Satellites

The DOD contined to participate in the geodetic satellite program during 1967. Satellites observed by DOD include: GEOS A, PAGEOS, NAVY NAVIGATION SATELLITES, SECOR and others. GEOS B (which carries an Army SECOR transponder, a NASA Range-Range Rate transponder, an Air Force Optical Beacon, and a Navy Doppler transponder in addition to laser reflectors and C-Band beacons) is to be launched shortly. The geodetic efforts will continue to provide more precise information about the Earth's size, shape, mass and variations in gravity and precise determinations of locations to support mapping, charting, and geodesy.

The Army Corps of Engineers began operations on a 30-station globe-circling network designed to provide a new determination of the Earth's equatorial radius, position critical range tracking stations, and provide scale to the PAGEOS network. The network advanced eastward from Hawaii traversing the U.S. and Canada to the continent of Africa. One SECOR satellite, EGRS IX, was successfully orbited in 1967 into a 2,000-nautical mile polar orbit.

Doppler information using primarily the NAVY NAVIGATION SATELLITES, GEOS-A and France's ALOUETTE was collected by the 13 permanent stations and four mobile vans. In addition, the tracking station at McMurdo Sound, Antarctica, was reactivated by the National Science Foundation. During 1967 the Navy determined from Doppler observations the positions of 18 stations to an accuracy of ± 25 meters with respect to the Earth's center-of-mass from Doppler observations. Additionally, the Doppler data was used to better define the model of the Earth's gravity field. Harmonic coefficients of the gravity potential have been extended to the twelfth order and degree. A lightweight, portable tracking station, called the GEOCEIVER, will be delivered shortly to replace the breadboard model which became operational during 1967. The GEOCEIVER will consist of a new receiver, antenna, and data package. It weighs approximately 80 lbs. and is designed to be transported by one man.

The PAGEOS satellite launched in June, 1966, is being observed by DOD and the Coast and Geodetic Survey for establishing a worldwide Geometric net of 43 stations. PAGEOS is a reflective 100-ft. inflatable sphere which is observed in relation to the star background. Observations have been accomplished from a total of 24 of the 43 stations.

With the development of a chopping shutter, Air Force PC-1000 cameras are able to observe passive satellites. The objectives now are to provide densification to support mapping and charting efforts, to supply data for radar calibration, and to position strategic locations such as Air Defense Tracking stations. The PC-1000 teams have completed radar calibration and ADT site positioning efforts and are now deployed for densification.

NAVY NAVIGATION SATELLITE System

A constellation composed of three NAVY NAVIGATION SATELLITES was maintained in operation during most of 1967. Three replacement satellites, with improved electronic components and power systems and an expected longer lifetime, were interjected into the constellation in the course of the year.

NAVIGATION SATELLITE System receivers are installed in all Fleet Ballistic Missile submarines and all attack carriers deployed to Southeast Asia, both to update the ship's interial navigation system and to provide data for the aircraft navigation systems prior to launch from the carriers.

On July 29, 1967, the Vice President of the United States announced that the NAVY NAVIGATION SATELLITE System had been released for use by civilian ships and that the shipboard receivers could be manufactured commercially on an unclassified basis.

Also during 1967, four small navigation satellite receivers, suitable for a man-to-back pack, were delivered to the Navy. These, along with the two sets delivered in 1966, were tested under simulated field conditions to determine how accurately they could locate themselves in relation to one another. They have now demonstrated accuracies equivalent to those achieved by surveying.

A satellite navigation receiver designed and manufactured for aircraft employment was delivered to the Navy in October and will be extensively tested in flight in cooperation with the Air Force during 1968.

SPACE GROUND SUPPORT

DOD National Ranges

The Air Force is realigning the management structure for its operation of the DOD ranges. This action will streamline and simplify the management chain, provide a more responsive, faster-reacting system, and save manpower. The realignment in the Air Force Systems Command (AFSC) replaces the National Range Division (NRD) by establishing as the range focal point the AFSC Deputy Chief of Staff for Operations. Within Headquarters USAF, the range monitoring functions have been placed under the Director of Space.

Range instrumentation continues to be improved through modernization of existing trajectory measuring systems and conversion of telemetry systems to operation in the Ultra High-Frequency (UHF) band.

Eastern Test Range--During much of this year, acceptance testing continued on the eight C-135 APOLLO/Range Instrumented Aircraft. These aircraft will provide support to DOD missile programs as well as the APOLLO program in areas not covered by land and ship stations. All eight aircraft will be operational by January, 1968. Data-acquisition capability of Advanced Range Instrumentation Ships is being improved to provide increased support to re-entry systems development and evaluation and space missions.

Western Test Range--The five APOLLO ships are undergoing operational testing and the entire fleet will be operational by March, 1968. Terminal-area scoring and recovery capabilities have been improved by the addition of a new bottom-mounted acoustical hydrophone and the acceptance of a new two-man submarine. Work continued on the TITAN IIIM launch complex in the Sudden Ranch area.

Satellite Control Facility--A substantial effort has been made to upgrade the overall capabilities of the Satellite Control Facility to support more numerous and complex satellite programs in the FY 1970-1975 era. Contracts have been negotiated to provide all tracking stations in the network with the Space Ground Link Subsystem (SGLS). This equipment will accomplish the conversion of all telemetry to the S-band and significantly improve tracking and command capabilities. A large addition has been approved for the Satellite Test Center to provide modern Mission Control Complexes, from which the on-orbit satellites are controlled on a round-the-clock basis. The new building will house an Advanced Data System (ADS) and the Expanded Communications Electronics System (EXCELS).

Space Detection and Tracking

SPACETRACK and the Navy SPASUR fence form the North American Air Defense Command's Space Detection and Tracking System, which detects, tracks, identifies and catalogues all man-made orbiting objects, both foreign and friendly. Specialized satellite information and specific system support are provided for NASA manned space flight operations and all Department of Defense satellite programs.

Continuing improvements are required to the SPACETRACK System to cover the increasing number of objects in space. To meet these ever-expanding needs, an evolutionary program of system expansion has been established. A new phased-array radar, designated the AN/FPS-85, it will be located at Eglin AFB, Florida, during 1968. This radar will significantly improve U.S. capability to maintain the surveillance necessary to support national space programs and national defense. Also, the Navy SPASUR has completed the frequency conversion of all transmitters and increased its main transmitter power.

AERONAUTICS DEVELOPMENT ACTIVITY

C-5A Heavy Logistics Transport Aircraft

The manufacture and assembly of the world's largest aircraft is on schedule. Roll-out is scheduled to occur in February, 1968. First flight is planned in June, 1968.

A B-52E is serving as a flying test bed for the TF-39 turbofan engine that will power the C-5A. First flight was made on June 9, 1967. All engine test objectives have been met and the program is proceeding on schedule.

A new hangar is under construction at Edwards AFB, California, to support the flight-test phase of the C-5A. The climatic hangar at Eglin AFB, Florida, is being modified to enable cold-weather testing of the entire aircraft.

F-111 Aircraft

The F-111A program has made very satisfactory progress during 1967. The contractors' Category I testing is continuing at Ft. Worth, Texas; Eglin AFB, Florida; and Peconic River, Long Island, New York. The Air Force F-111A Category II test program is being conducted at Edwards AFB.

An accelerated service test program was initiated in June, 1967, at Nellis AFB, Nevada, by Tactical Air Command's Combat Crew Training Wing. This program is training the personnel for the first operational F-111 squadron, which is now being activated. This operation has been highly successful in every respect and subsystem operations have been extremely reliable.

Tactical Air Command's first production aircraft was delivered from Ft. Worth, Texas, to Nellis AFB on October 16, 1967. On this flight of more than a thousand miles the aircraft used the automatic terrain-following feature for the entire trip and flew at a constant 1,000 feet above the ground at speeds slightly less than the speed of sound.

Development of the FB-111A, a strategic-bomber version of the F-111, is progressing on schedule. The first prototype FB-111 flew in July, 1967. Advanced avionics development for this aircraft continues to indicate on-schedule deliveries.

The F-111C, being developed for the Australians, and the F-111K, being developed for the British, are also proceeding on schedule.

The first prototype RF-111, a reconnaissance version of the F-111A, was test-flown on December 17. This aircraft includes advanced avionics components. The reconnaissance sensor pallet, totally contained in the weapons bay of the aircraft, will be flown on the prototype RF-111.

Preliminary carrier trials of the Navy's F-111B are scheduled for March, 1968, followed by November, 1968, delivery of the first airplane incorporating the carrier suitability changes.

Advanced Tactical Fighter

The Air Force has completed a Concept Formulation Package and recommended development and production of a new tactical fighter, the F-X, which will provide advances in performance necessary to maintain U.S. air superiority. It will be designed to replace the F-4, and will emphasize air supremacy but still retain a substantial air-to-ground capability.

The Navy has submitted its Technical Development plan for a new two-place, twin-engine, variable-sweep-wing, multi-mission fighter/attack aircraft, the VFAX. This aircraft is designed to replace the Navy's multi-mission F-4 and, while primary emphasis has been placed upon its air-to-air capability, it will also have all-weather air-to-ground capability. The Navy has completed a careful trade-off analysis to insure that the new fighter will be light-weight and compact enough for efficient use aboard the attack carriers.

The services are continuing to study the feasibility of meeting their joint requirements with a common aircraft.

A-7 Light Attack Aircraft

The Navy A-7A is a TF-30-P6 turbo-fan-powered, single-place, visual light attack aircraft to replace the A-4. It can carry a more versatile mixture of ordnance, and it can deliver weapons more accurately and at increased range. The first operational squadron was deployed in the fall of 1967.

Deliveries of the Navy A-7B, equipped with the higher-thrust-rating TF-30-P8 engine, will begin in early 1968.

The joint programs for the Air Force A-7D version of the Navy A-7E are progressing on schedule. The A-7D will use the TF-41 engine. The A-7E continues with the TF-30. Both versions incorporate improved avionics to provide greatly increased accuracy of navigation and weapons delivery. Production of these latter two versions will commence in 1968.

XB-70

Two XB-70 aircraft were built. The Number 1 airplane was first flown in September, 1964, and the first flight of Number 2 occurred on July 17, 1965. The Number 2 airplane was lost in an accident on June 8, 1966.

Both airplanes were used in a flight-test program from the first flight of the first airplane until the Number 2 airplane was lost. Objectives of that program were to establish airworthiness of the vehicles, investigate design feasibility, determine handling qualities and demonstrate Mach 3 flight for 30 minutes sustained. Those objectives were met.

The remaining XB-70 is being used in the joint USAF/NASA XB-70 flight research program. Primary objectives of that program are to improve stability and control and handling qualities, dynamic structural loads, engine-inlet matching and general performance. Some of the objectives are in support of the National Supersonic Transport (SST) Program. Present plans call for conducting the program through FY 1968, but NASA has the option of continuing the program beyond FY 1968.

Coin Aircraft

The OV-10A is a twin-engine turboprop aircraft with short takeoff and landing performance on unimproved fields, roads and aircraft carriers without using arresting gear. In addition to aerial reconnaissance, artillery and naval fire spotting, aerial photography, helicopter escort, forward air control, and close suppression fire, the OV-10A can also perform light logistic and utility missions.

First flight of the prototype OV-10A took place on June 16, 1965. The Navy conducted an early evaluation of the prototype airplane. Phase I of the Navy Preliminary Evaluation (NPE) program was completed on March 21, 1966, and several deficiencies were noted. A concerted effort by the Navy and the contractor solved the major difficulties. The principal changes to the aircraft were an increase in wing span and up-rating of the turboprop engines. A contract was released for 223 aircraft, 109 for the Air Force and 114 for the Marine Corps on October 15, 1966. Modification to the original contract for an additional 48 Air Force airplanes was executed on October 10, 1967.

Helicopter Development

AH-56A (CHEYENNE)--The army began development of the AH-56A in March, 1966. The first of ten prototypes was rolled out in April, 1967, three weeks ahead of schedule. First flight was successfully completed on September 21, 1967, one day ahead of schedule. Initial flight tests results are highly satisfactory and indicate that performance requirements will be met, and the development program continues to meet all major milestones. The CHEYENNE is an optimized armed helicopter for use during the 1970's, and is designed to replace the armed UH-1C utility helicopter.

AH-1G (HUEYCOBRA)--Pending availability of the optimized AH-56A, and in response to an urgent operational requirement for an interim improved helicopter in Vietnam, the Army has developed and is procuring the AH-1G (HUEYCOBRA). This is a product improvement of the armed UH-1 now employed in Vietnam. Its armament includes machine guns, rockets and grenade launchers. Production deliveries of the AH-1G began in May, 1967, and the first AH-1G's were deployed in Vietnam in August, 1967.

CH-53A--This Marine Corps assault transport helicopter was deployed to Southeast Asia in December, 1966, within two months after completing operational testing. It has demonstrated exceptional operational ability, maintainability and reliability. In addition to its normal transport activities, it has been used to retrieve 265 downed aircraft. On occasion the aircraft has lifted 20,000-lb. loads externally and in other instances carried 75 combat-equipped troops.

V/STOL Development

CL-84--The twin-engine tilt-wing V/STOL CL-84 aircraft was subjected to a limited 20-hour Tri-Service test to evaluate it for possible military potential. Following the completion of Tri-Service tests, the only CL-84 flying prototype was destroyed in a September 12, 1967, crash. The Canadian Government is purchasing three of the aircraft for military operational suitability testing. The nature and extent of future U. S. interest in the CL-84 will be determined after a complete analysis of the Tri-Service test report.

X-22--The X-22 ducted propeller research aircraft is undergoing regular flight testing in all operational modes, with an excess of 100 flights accumulated on the single test vehicle. Military Pilot Evaluation is scheduled to start January, 1968. Following these tests a variable stability system will be incorporated, allowing the aircraft to simulate the control characteristics of other V/STOL types.

US/FRG V/STOL Fighter Program

The United States and the Federal Republic of Germany are participating jointly in a program which if carried to completion will result in the development and evaluation of 12 prototype V/STOL fighter type aircraft. The program was initiated in December, 1964, and its cost is shared between the countries. Bilateral agreement is required prior to proceeding with each major phase of the program, and either country may withdraw at the end of any phase.

The first phase, System Definition, was completed in November, 1967. The data from the System Definition analyses were still undergoing evaluation at the end of the year.

X-15 Research Aircraft Program

The three X-15 airplanes were designed to achieve speeds of up to Mach 6. Following an accident in November, 1962, X-15 Number 2 was rebuilt and modified to expand its performance envelope from Mach 6 to Mach 8. The highest Mach number achieved so far is 6.7 and the highest altitude is 67 miles.

The X-15's are being used primarily as carriers of instrumentation packages to collect data at the high speeds and altitudes for various studies, including environmental, improving components for future aerospace vehicles, and basic aerothermodynamic research.

X-15 Number 3 crashed on November 15, killing the Air Force pilot. This was the first fatality in this nine-year-old program, and the first time one of the three vehicles was damaged beyond repair. Cause of the accident remains to be determined.

Presently approved Air Force-sponsored X-15 experiments are expected to be completed near the middle of Calendar 1968.

Aeromedical Evacuation Modernization Program

The program was initiated on December 31, 1966, as the result of a decision to procure eight off-the-shelf jet transports to meet domestic aeromedical evacuation requirements. On August 31, 1967, it was announced that the DC-9 had been selected and would be designated the Air Force C-9. These aircraft will be specifically configured for the aeromedical evacuation role and will enter the inventory beginning August, 1968. Options for 17 additional aircraft have been obtained. These aircraft, if procured, would be used to complete the domestic aeromedical evacuation system modernization and to modernize the overseas aeromedical systems.

F-12

The Air Force is continuing R&D effort on the F-12. During 1967, this effort has been oriented toward improvement of the fire control system, packaging that system for installation in the YF-12 airframe, and changing the design of the forward airframe to accommodate this installation. To provide for early flight test data, a YF-12A is being modified to more closely approximate the production configuration. This continuing engineering development program is intended to provide a modern design and reduce the lead time to an operational capability.

Advanced Manned Strategic Aircraft (AMSA)

The Air Force has a continuing program which has defined the design and characteristics of an advanced bomber. Critical development efforts are being pursued to reduce the uncertainties that will arise if a decision is made for full-scale development of an advanced bomber. The 1967 study has consisted primarily of defense penetration analyses and the impact upon bomber design and penetration capability of a variety of penetrations aids.

In addition to the 1967 study, the Air Force has been conducting advanced development in avionics and propulsion. This includes the flight-testing of various advanced equipments to provide more accurate weapon delivery and better warning and location of enemy defenses. The propulsion effort is providing demonstration engines which are designed to operate efficiently over a wide range of speeds and altitudes.

National Clear Air Turbulence Program

The Department of Defense has been assigned responsibility for that portion of the National Clear Air Turbulence Program concerned with observations, measurements, special reconnaissance, and development of devices to detect turbulence ahead of an aircraft in flight.

The Department of the Air Force, as representative of the DOD, is actively participating in the preparation of a detailed national plan to attack the problems created for aircraft in flight by clear air turbulence. During 1967, an office will be established at Headquarters Air Force Systems Command to manage the DOD actions and to coordinate such actions with those of NASA, ESSA and FAA.

Aircraft Survivability

This program deals with the numerous modifications which enhance aircraft survivability in a hostile environment. These include internal fuel cell foam, external void filler foam, self-sealing fuel cells and lines, fire extinguisher systems, backup flight controls, revised fuel system plumbing and selective use of steel and ceramic armors. Modification of F-105, F-4 and RF-101 aircraft now in progress is expected to reduce their vulnerability 40 - 60%. Modifications to the F-111 and A-7 are in final stages of study.

SUPPORTING RESEARCH AND TECHNOLOGY

Over-the-Horizon Detection

The Department of Defense-developed OHD radars, utilizing ionospheric refraction of radar energy, have demonstrated a capability to detect missiles and aircraft beyond the radar or line-of-sight horizon. In contrast with earlier systems, which were limited to detection ranges of several hundreds of miles the OHD technique provides ranges of several thousands of miles. Laboratory and field evaluations are continuing, in order to improve our missile early-warning capabilities and operational aircraft movement observations. The technique may also be applied to air traffic control operations. An operational system is under development to add significantly to our missile early-warning capabilities.

Spacecraft Technology and Advanced Re-Entry Tests (START)

The Air Force is continuing to develop technology for maneuverable-entry spacecraft. Data acquired is vital to the design of future manned and unmanned recovery spacecraft. Two projects, designated PRIME and PILOT, have been supported under this program.

The PRIME (Precision Recovery Including Maneuvering Entry) successfully demonstrated that an unmanned lifting-body spacecraft can be maneuvered from orbital flight environment to a precise recovery point. In the three flights made, aerodynamic control was tested from entry speeds through the hypersonic regime down to Mach 2.0.

The Project PILOT (PIloted LOw-speed Tests) vehicle (designated X-24A) is a manned, low-speed test aircraft version of the Project PRIME vehicle. Its purpose is to complement the flight regime of the PRIME vehicle, flying below Mach 2.0. It will be launched from a B-52 aircraft, providing stability and control data from Mach 2.0 to horizontal landing. The flight tests will be conducted as a joint AF/NASA program.

Applications studies have been under way to determine specific configuration and related technologies required for the next generation of military spacecraft. A multipurpose reusable spacecraft (MRS) appears the most promising concept. Expandable structures for space crew air-locks and space rescue (escape) application are also being considered.

Space Power Equipment

The DOD continued to develop various concepts for meeting anticipated electrical power requirements of future satellites. The accomplishments of 1967 include further development of fuel cells for manned and unmanned satellites and fabrication of experimental flexible solar-cell arrays.

The fuel cell is an electrochemical device which converts hydrogen and oxygen to useful electricity, heat, and water. Present unmanned short-life vehicles use primary batteries. Successful completion of this program will increase power and life over current missions, decrease payload weight through power supply weight reduction and, in general, allow missions which are presently impossible.

Rigid solar-cell panels, in conjunction with rechargeable batteries, have been used to provide electricity for the majority of long-duration space flights. Flexible solar-cell arrays presently under development are rolled up like window shades, and may be reliably deployed and retracted in space. These flexible arrays will provide much more electrical power at less weight and volume than is now possible. The deployment and retraction feature will also reduce vulnerability to radiation and improve maneuverability.

Rocket Propulsion Technology

The Air Force exploratory development effort in rocket propulsion is intended to expand the technological base from which new ballistic delivery, space maneuver and tactical air systems can be developed. During 1967 there was an increase in emphasis on work applicable to airborne tactical systems.

In the delivery and space systems area, the Air Force Rocket Propulsion Laboratory (AFRPL) under a Space System Division program has completed three static firings of 156-inch-diameter motors configured as the first, second, and third stages of a multipurpose space or ballistic vehicle. These tests illustrated the potential of large submerged ablative nozzles, high burn-rate propellants and omniaxial liquid injection thrust vector control for large solid motors. The technology being developed will provide the base for the next generation of large boosters.

In line with providing the necessary facilities to simulate space environments and support our technology programs, a new space simulation test chamber was installed at AFRPL. This facility provides a unique capability for exploratory development of actual propellant and component performance in space. It simulates altitudes to 100 miles, the cold blackness of outer space, and solar radiation.

General work on air augmentation continues in the airborne systems area. AFRPL, in conjunction with the Air Force Armament Laboratory, is developing a target missile called the Sandpiper. Its primary purpose is to provide a hybrid propulsion target missile which can simulate the flight characteristics of the best high-performance aircraft a potential enemy might produce in the next decade. Other potential applications for the hybrid rocket engine include air-to-air missiles having a capability for a midcourse and terminal maneuvers, reconnaissance and surveillance missiles, and decoy missiles.

Gravity Gradient Stabilization for Satellites

The Department of Defense Gravity Gradient Equipment (DODGE) was launched on July 1, 1967. This variable-geometry satellite uses extendable booms and magnetic damping techniques to achieve three-axis stabilization at near-synchronous altitude. It is equipped with two slow-scan television cameras pointing Earthward. To measure the degree to which stabilization has been achieved, this system provided the first color pictures of the Earth from near-synchronous altitude. A substantial amount of test data is currently being analyzed. Two-axis gravity-gradient stabilization has been used by all NAVY NAVIGATION SATELLITES launched since 1962, employing a single top-mounted boom.

Despun Antenna Test Satellite (DATS)

An electronically despun antenna test satellite was successfully orbited as a secondary payload on the July, 1967, communication satellite launch. This satellite has a communication package which receives and transmits through a high-gain antenna, which is always directed towards the Earth. This satellite is performing essentially as predicted and significant communications experiments have been conducted and will continue.

Solar Radiation Monitoring Program

The Naval Research Laboratory continued its studies of solar radiation, which began in 1960. Rocket coronagraphs of white-light corona and extreme ultraviolet disk and corona were obtained by soundings in May and October. The May flight was made during a partial solar eclipse that provided an opportunity to record valuable data on the corona of the Sun, and the October flight occurred early in the beginning solar maximum period. It is anticipated that continuing flights to obtain rocket coronagraphs, at the rate of one or two per year, will provide continuity in the observation of the far-out corona extending through the solar cycle.

Turbine Engine

Technology advancements in turbojet and turbofan engines have been very gratifying. They are incorporated in four new types of aircraft engines now under investigation. One of these has progressed into the full development and production phase, while the other three are in the initial, engine demonstrator, phase of development.

The TF-41 is an advanced turbofan engine which is being developed and produced for the Air Force A-7D attack aircraft.

A direct-lift engine and a vectored-thrust, lift-cruise engine are being demonstrated prior to initiation of full development under the vertical or short takeoff and landing (V/STOL) program. The direct-lift engine, which would operate only during takeoff, landing and hover of an aircraft, is a very high thrust-to-weight ratio engine. It is being developed under a joint United States-United Kingdom cooperative research and development program. The vectored-thrust lift-cruise engine offers deflected thrust to assist in takeoffs and landings and to provide forward thrust for all other maneuvers. This engine also has significant improvements in thrust-to-weight ratio, as well as reduced fuel consumption for cruise and maneuvering. Both of these engines may see first application in a V/STOL Tactical Fighter being considered for prototype development by ourselves and the Federal Republic of Germany.

For our advanced strategic aircraft the Air Force will complete the demonstration of a sophisticated turbofan engine with afterburner during the next year. This engine incorporates technological advancements which will permit it to operate efficiently over a broad range of altitudes and velocities.

Advanced Turbine Engine Gas Generator (ATEGG)

This program is providing the means to demonstrate functionally advanced turbine engine technology through the development of demonstrator engines. It will provide sufficient testing of advanced turbine engine design concepts to give confidence that these concepts can be used in future propulsion systems. The ATEGG Program is a continuing effort in which four contractors are presently participating.

The contractors are working on turbine engine hardware and testing engines at very high temperatures with advanced compressors. The goal is to provide improved high subsonic/supersonic flight capabilities with better fuel consumption.

Turboshaft Engine Project

The Army has initiated a two-year development program in which each of two contractors will build and test a 1,500 shaft horse power (shp) demonstrator engine to demonstrate advanced gas turbine engine technology. The goal is to produce engines with 40% less weight and 25% lower specific fuel consumption than current production engines of comparable power rating.

VTOL Integrated Flight Control (VIFC)

The basic program objective is to provide control design criteria and equipment technology to assure safe and effective control systems design for possible future operational VTOL fighter and transport systems with emphasis on low-visibility landing capability. The basic problem is that there is a lack of adequate technology for implementing design and development of optimized control systems. Current knowledge is inadequate for providing control systems that are satisfactory for operational-type vehicles being flown by operational pilots under adverse weather conditions.

This program will utilize a modified XV-4A aircraft as a test bed.

Load Alleviation and Mode Stabilization (LAMS)

The LAMS Program will demonstrate the capability of advanced flight control techniques to alleviate gust and maneuvering loads and control structural oscillations of large aircraft through the use of conventional control surfaces and appropriate feedback information. This program is aimed at more than doubling the structural life of current and future aircraft.

This technology will be demonstrated on a highly instrumented B-52 in January, 1968.

Total In-Flight Simulator (TIFS)

This program will develop an aircraft capable of duplicating, in flight, the flight path, motions, attitudes, control system characteristics, and cockpit environment of large aircraft such as the C-5A, SST, and AMSA. It will be used for the investigation and development of handling qualities, cockpit displays, instrumentation, and control systems of such aircraft.

TIFS will utilize a C-131 aircraft as the basic airframe. A computer will process the pilot's control inputs to operate the throttles and special control surfaces in such a manner as to make TIFS fly like the aircraft being simulated. A realistic cockpit environment will be provided by interchangeable nose sections which represent the particular aircraft being investigated.

Preliminary visibility tests of the proposed SST configuration will begin in March, 1969.

Airborne Warning and Control System (AWACS)

The Airborne Warning and Control System (AWACS) will be developed for use by the Tactical Air Command and the Air Defense Command. It will provide command, control and communications for quick-reaction global deployment with the Composite Air Strike Force (CASF) to any limited-war area. It will also provide the Air Defense Command with a survivable warning and control environment for air-defense interceptors, both in the United States and worldwide.

The AWACS will be self-contained in a subsonic jet aircraft and will include a surveillance radar, a beacon tracker, a mixture of long- and short-range communications, data processing and displays. The aircraft will carry a crew of about 35 operators. The surveillance radar is being developed to have the added capability of detecting and tracking low-flying aircraft against a background of clutter signals reflected from the ground.

SHED LIGHT

SHED LIGHT is the USAF program to provide increased night operational capability to our tactical forces as rapidly as possible.

Developmental systems are being tailored to satisfy a variety of operational requirements. These involve self-contained night attack systems for interdiction operations; aircraft specifically configured for defense of airfields, forts, hamlets, and troop concentrations; hunter aircraft for near-real time reconnaissance to work with conventional strike aircraft; and aircraft to give forward air controllers an effective around-the-clock capability.

In addition to these efforts, approximately 70 supporting development projects involving Low Light Level Television (LLLTV), Forward Looking Infrared (FLIR), Downward Looking Infrared (DLIR), lasers, radar, optical sensors, displays/processing/data transmission methods, illumination, target marking improved navigation, and weapon delivery are under way at the present time to further enhance our ability to operate at night.

Tests of developmental efforts to date have been satisfactory, and plans are being formulated to modify selected aircraft for operational use.

COOPERATION WITH OTHER GOVERNMENT AGENCIES

The Department continues to emphasize cooperation with other agencies, particularly with NASA. Coordination and cooperation occurs at all levels, varying from informal discussions to formally scheduled meetings with various boards and committees.

Aeronautics and Astronautics Coordinating Board

Four meetings were held during 1967. Coordination was accomplished in such areas as proposed NASA/DOD facilities, reusable launch vehicles, satellite communication systems, control-guidance and navigation, ground environmental support, advanced cryogenic rocket engines, and space science programs.

Manned Space Flight Policy Committee

This Committee, established last year, facilitates the exchange at top-management level of viewpoints and information of importance in planning of the manned space flight programs of NASA and the DOD. During 1967 the Committee met three times.

DOD Support of NASA

The DOD support of NASA totals about $400 million. Over 400 separately identifiable activities are involved. Among the major items of support are the operation of the ranges for manned and unmanned spacecraft launches and host-base support by the Air Force, major construction by the Army, and operation of the recovery fleet by the Navy. In addition there are many other activities of lesser magnitude. Selected examples follow:

ARMY

Construction Support--The Corps of Engineers continued to support NASA by providing real estate acquisition services, and design and construction of facilities at the John F. Kennedy Space Center, the Mississippi Test Facility, and the Electronics Research Center. The construction of facilities by the Corps of Engineers at the Manned Spacecraft Center was completed. The magnitude of this support exceeded $90 million on a reimbursable basis.

Lunar Activities--The Army Map Service assisted NASA by producing large-scale topographic maps and photomaps of potential APOLLO lunar landing sites, using LUNAR ORBITER photomaps. An extremely detailed map of the vicinity of the SURVEYOR I landing was prepared from SURVEYOR photographs to assist geologists and engineers in interpreting lunar surface characteristics. Studies were begun to improve the lunar control network through the application of information obtained from the LUNAR ORBITER series. The Army Material Command conducted mobility tests on two simulated lunar vehicles equipped with wheeled systems. The Corps of Engineers designed and fabricated field-test support equipment and is providing other technical assistance in development and evaluation of lunar core drills.

Range Support--White Sands Missile Range continued to provide support to a number of NASA projects utilizing this Army-managed National Facility. Quality assurance and orbital range instrumentation support was provided on a reimbursable basis. Non-reimbursable range services (e.g., operation of range instrumentation, data collection and reduction, photographic services, missile recovery services, meteorological services, range communications) were furnished in support of numerous active NASA programs.

NAVY

APOLLO--The Navy will, as during the GEMINI and MERCURY programs, provide the recovery fleet for APOLLO flights as required to assist in that program.

Medical Projects--The Naval Aerospace Medical Institute, Pensacola, Florida, provides facilities and key personnel to assist NASA in the study of space-related medical phenomena. Some of the studies being performed include: the effect of very strong magnetic fields on man and animals, ground investigation of flight experiments involving primates in long-duration zero-gravity condition, vestibular function and visual orientation tests and the biological effects of proton radiation.

Construction Projects--Work performed for NASA includes design, construction, inspection, and contract administration of facilities for space vehicles, space tracking and data acquisition.

AIR FORCE

Test Range Support--The Air Force Systems Command provides extensive range support to NASA manned and unmanned space programs. This includes range operations plans and support, range instrumentation, data acquisition, transmission, processing and reduction, precision-measurement equipment calibration and repair, industrial support, launch complex control and support operations and facilities engineering on the Eastern and Western Test Ranges. A significant portion of the operation and maintenance of facilities at Cape Kennedy Air Force Station is in direct support of NASA.

Launch Vehicle--The long-standing Air Force provision of launch vehicle support to NASA has been continued. The Deputy for Launch Vehicles, Space and Missile System Organization provided management, technical and procurement assistance in the acquisition of ATLAS-AGENA and THOR-AGENA launch vehicles. This support includes development, engineering, production, configuration management and launch of the vehicles.

APOLLO--The Arnold Engineering Development Center provided the following APOLLO support:

a. Environmental verification tests for the J-2 engine were conducted from January to July.

b. The static and fluctuating pressure environment for the SATURN V launch vehicle were conducted in the 16-foot Supersonic Tunnel.

c. Testing was continued in the Hypersonic Tunnel to measure the flow field around the base of a SATURN rocket cluster model.

d. Environmental tests and mission duty cycle simulation of the lunar module Descent Engine were conducted to evaluate system performance.

e. Qualification testing of the APOLLO SERVICE MODULE rocket propulsion system was continued to assure that the system provides the high reliability standards required by the lunar mission.

Mapping and Charting--The Aeronautical Chart and Information Center has compiled and reproduced lunar charts for APOLLO mission planning.

ATOMIC ENERGY COMMISSION

CHAPTER
V

INTRODUCTION

In 1967 substantial progress was made in the joint AEC/NASA nuclear rocket program. Highlights were: (a) successful operation of the PHOEBUS-1B reactor at power levels approaching 1,500 megawatts for 30 minutes; (b) cold-flow testing of the first in the series of large-diameter reactors called the PHOEBUS-2CF to verify the structural integrity of a high power-density, 5,000-megawatt reactor called the PHOEBUS-2A tested during the third quarter; (c) successful test of the NRX-A6 reactor at full power of about 1,100 megawatts for approximately 60 minutes; (d) assembly and checkout of the first ground-experimental engine, the XECF (a cold-flow test article); and (e) completion of Engine Test Stand No. 1, the facility which will be used to test the XECF, and later, the XE-1. All these activities were directed toward establishing a firm base of technology to advance space propulsion performance for missions beyond APOLLO.

During the year, the AEC continued its program for developing and testing nuclear radioisotope electric power units for space use, and for producing technology needed for a family of long-lived reactor systems which will supply power from the 100-watt to the megawatt range. By the year's end, substantial progress had been made in developing the technology required for space missions of the more distant future -- technology that will make possible the higher temperature capability and more efficient power conversions demanded by safe, reliable, and more economic systems performance while at the same time satisfying the expanding needs for space electric power.

NUCLEAR ROCKET PROPULSION

In the joint AEC/NASA nuclear rocket program, the most significant achievements during the year evolved from developmental work on the graphite reactor and engine system technology -- the mainstream effort in the program. Complementing this effort was an extensive program of supporting research and technology to enhance the performance capabilities of nozzles, turbopumps and control systems employed in reactor and engine system tests; to gain a better understanding of component behavior in these systems; and to provide basic data on the effects of radiation on materials.

Reactor and Engine System Technology Development

The PHOEBUS-1B reactor tests were conducted by the Los Alamos Scientific Laboratory (LASL) as a part of its overall technical program to increase the temperature, power level, power density and endurance capabilities of graphite reactors.

The full-power test of the PHOEBUS-1B was conducted on February 23. During this test, the reactor was operated at power levels approaching the 1,500-megawatt design rating. Total operating time for the run was approximately 46 minutes, of which about 30 minutes were above 1,250 megawatts. Approximately 10 minutes of power operation had been accumulated two weeks earlier during a reactor and instrumentation calibration test.

Data from the LASL PHOEBUS-1B experiments indicated the reactor test profiles were as planned during startup and shutdown. Thermocouple drifts caused the reactor power to decrease gradually during the full-power run. The run was successful in meeting the major objectives of the full-power test. Fuel-element corrosion resistance was demonstrated to be greatly improved due to a new processing technique developed by LASL.

Concurrently with the PHOEBUS-1 reactor work, LASL began to design and fabricate the high-power test reactors required to carry out Phase 2 of the technical plan. The first of these reactors, a cold-flow assembly called the PHOEBUS-2CF, was moved to the cell on June 16 and tested under cold-flow conditions during July and August. The objectives of the tests were to:

a. Verify the structural and mechanical integrity of the reactor design under hydrogen flow conditions;

b. Evaluate the facility and reactor behavior during various reactor startup ramp flow program profiles such as those planned for the PHOEBUS-2A hot reactor;

c. Verify instrumentation and control drum performance at the low-temperature cold-flow conditions; and

d. Confirm design analyses through detailed measurement of reactor flow rates, temperatures, and pressures.

More than a dozen runs were made over a five-week period. A number of minor leaks in the pressure vessel which surrounds the reactor and auxiliary coolant lines were located and repaired. An auxiliary coolant flow line, found to be undersize, was modified to obtain the additional coolant flow needed. Reactor and facility behavior was mapped, and a number of changes were made to obtain more stable reproduceable start profiles. Substantial improvements to the facility emergency flow shutdown systems were also made as a result of knowledge of the facility system behavior gained during these tests.

Reactor instrumentation and control drum performance were excellent, and reactor pressure drops and flow rates measured were generally in excellent agreement with predictions.

Hardware for the second test reactor, called the PHOEBUS-2A, is now being assembled in the Reactor Maintenance, Assembly and Disassembly building (R-MAD) at the Nuclear Rocket Development Station in Nevada. This reactor is a scale-up of the 1,000 to 1,500-megawatt KIWI/NRX/PHOEBUS-1 reactor design. Hot-testing of the PHOEBUS-2A is scheduled for the first quarter of 1968.

Assembly of the major components of the first XE engine, a cold-flow assembly (no uranium fuel in the reactor core), was completed in the second quarter of this year. This engine, called the XECF, is to be used to verify that Engine Test Stand No. 1 (ETS-1) is ready for hot engine testing and to investigate engine startup in the test stand under simulated altitude conditions.

In addition to the work on the XE Cold-Flow engine, assembly of the first "hot" engine was begun.

SPACE ELECTRIC POWER

Space Radioisotope Power Systems

Two Pu-238-fueled SNAP-19 flight units (2 generator modules per unit), designed to provide a total of approximately 50 watts of electrical power for experiments on board NASA's NIMBUS B weather satellite, completed flight-acceptance testing, and were prepared for shipment to NASA for a launch scheduled in early 1968. Several electrically heated prototype generators have accumulated a combined total time of operation in excess of 40,000 hours.

Development continued on the SNAP-27, a Pu-238-fueled radioisotope thermoelectric generator to power NASA's APOLLO Lunar Surface Experiments Package (ALSEP) program. The SNAP-27 is designed to produce 50 watts per generator. Such generators have successfully completed dynamic and environmental qualification testing; electrically heated prototype generators currently under test have operated for over 10,000 hours. Training units were shipped to NASA early in the summer of 1967, and the first flight generator (non-fueled) completed component acceptance testing in late fall. The LUNAR MODULE fuel cask was redesigned from beryllium to graphite. The fueled SNAP-27 generator weighs only 40 pounds.

Development of the SNAP-29 Pu-210 radioisotope thermoelectric generator was redirected from a specific 500-watt, 500-lb. flight-oriented system to a modular system using discrete building blocks to produce multihundred-watt electrical systems. The heat-rejection mode was also changed from a sodium-potassium (NaK) system to a heat pipe system. It is anticipated that the SNAP-29 will be capable of supplying up to 2 kilowatts of electrical power for applications lasting approximately three months. An effort is now being made to develop a ground demonstration of the system technology.

Part of the so-called "lightweight" thermoelectric development program was directed towards the design of a 2-watt-lb., 30-watt isotope-fueled generator to fulfill navigation and communication satellite requirements for the 1968-1971 period. Accelerated tests indicated that a lifetime of greater than two years can be achieved. The lightweight thermoelectric generator concept uses radiant thermal coupling between the heat source and thermoelectric panel; its performance is relatively insensitive to configuration or to type of fuel.

Space Reactor Power Systems

SNAP-10A Ground Test. The post-operation examination of the SNAP-10A ground test unit was completed in 1967, and revealed no life-limiting problems or unexpected conditions. The ground-test unit was identical to the flight system, which was launched in 1965 and was successfully operated in space for 43 days before being shut down as a result of failure of the spacecraft electrical circuitry.

SNAP-8

The SNAP-8 reactor is a scaled-up version of the SNAP-10A reactor, and is being developed to provide a 10- to 30-electrical kilowatt capability with thermoelectrics (mid-to-late-'70's) or a 30-to 50-Kw capability with the NASA-developed SNAP-8 mercury turbogenerator. Work proceeded on all phases of the SNAP-8 demonstration reactor (S8DR), which is scheduled for power testing in 1968.

SPACE-DIRECTED ADVANCED TECHNOLOGY DEVELOPMENT

Advanced Radioisotope Power Concepts

Preliminary design studies of two 100-watt thermionic power generator modules using curium-244 and polonium-210 as isotopic heat sources, were completed in the first half of 1967. The modules are to be used as building blocks for space electric power systems in the 500-watt(e) to 2-kilowatt(e) power range. It is planned to continue towards a ground-test demonstration of the thermionic module in the 1970-1971 period.

Advanced Space Reactor Concepts

The AEC during 1967 continued development of three basic advanced reactor concepts:

a. The liquid metal-cooled reactor.

b. The in-core thermionic reactor.

c. The high-temperature advanced gas-cooled reactor.

These reactors are being developed to meet future space power needs for long-endurance systems having electrical outputs in the hundreds-to-thousands of kilowatts range. However, because available resources must be applied to the concepts of widest potential application, work on the advanced high-temperature gas-cooled reactor will be terminated in 1968.

In 1967 the liquid metal-cooled reactor program concentrated mainly on materials research and development investigations, supported by some basic-reference reactor design studies at several power levels of interest. The in-core thermionic reactor research program was directed towards the demonstration of thermionic fuel elements capable of long endurance operation times of 10,000 hours.

The gas-cooled reactor program concentrated on fuel element development; specimens of the fuel for the system were successfully tested under operating conditions.

Space Power Conversion Technology

AEC development of the organic Rankine-cycle thermal electric system will be continued during 1968. The major 1967 effort in this area sought to establish fluid properties and component design methods.

SPACE NUCLEAR SAFETY ACTIVITIES

The SNAP-19 radioisotope thermoelectric generator (RTG) to be used on NIMBUS-B was subjected to an extensive safety evaluation, which is continuing, bringing together representatives of the various disciplines of the scientific and technical community. A similar evaluation is in progress for SNAP-27, to be used as the APOLLO Lunar Surface Experiments Package (ALSEP) power supply.

Studies of fuel and capsule responses to their operational environments were continued. Primary advanced technology programs include investigations of various plutonium fuel candidates for future systems, intact re-entry heat sources, and methods for locating and recovering space nuclear systems following random or controlled atmospheric re-entry.

SPACE ISOTOPIC FUEL DEVELOPMENT

Polonium-210

Polonium-210 is being developed for radioisotopic power applications which demand high "specific power" (thermal power per unit volume or weight) and a minimum of shielding, and are of limited duration. There were studies, which are continuing, of polonium-rare earth compounds that remain chemically and physically stable at high temperatures under vacuum or inert atmosphere environments.

During the year, AEC continued a program begun in 1966 to develop and provide a polonium-210 fuel form for the SNAP-29. Methods were instituted to increase the separation and purification capacity for polonium-metal, the starting material for fuel form compounds. Processes must be improved so that the estimated costs of producing heat sources of this isotope can be reduced by decreasing the time lapse between discharge from the production reactors and delivery of the heat sources.

During 1967, efforts were initiated to determine the characteristics of curium-244 fuel forms -- including a study of the compatibility with encapsulating materials up to 2,000° C. Fuel forms have been prepared and partially characterized as to chemical, physical, radiation, and other properties; and capsule-closure sealing methods and design are under investigation. Methods for the processing of curium fuel forms are also being developed.

Plutonium-238

During 1967 there was continued development of the metal, alloy, and oxide fuel forms of plutonium-238, for use in radioisotopic power units. Process development of plutonium dioxide microspheres was one of the items of research. Desirable properties of this material include an inherently favorable half-life (87.5 years) and a fuel form (PuO_2 microspheres) which is relatively inert chemically and biologically, has a high melting point, exhibits thermal, chemical, and radiation stability, and is relatively easy to handle. Heat sources were fabricated of the oxide fuel form for the SNAP-19 and SNAP-27 programs.

Also during the year, the DART microthruster, an isotopic propulsion device for positioning a spacecraft in space, was designed, fueled and demonstrated successfully in a simulated space environment.

An alternate method to improve the economics and efficiency of processing the plutonium-238 oxide fuel was developed. Incorporated in the process is a method of reducing the neutron radiation. A pilot-plant demonstration of the new processes is scheduled for the near future.

SATELLITE-BASED DETECTION OF NUCLEAR EXPLOSIONS IN SPACE AND IN THE ATMOSPHERE

Eight AEC-instrumented VELA nuclear test detection satellites are now in orbit performing their limited test-ban treaty monitoring functions. The latest pair were placed in orbit on April 28, 1967, using a TITAN IIIC booster, and, following "station keeping" maneuvers, the two satellites settled down in 180° spaced positions on a near-circular orbit of about 60,000 nautical miles radius.

The new satellites are in orbits comparable to the previous six, but a redesign of the spacecraft makes it possible to maintain one axis oriented toward Earth at all times. This allows instrumentation for the detection of optical radiations emanating from nuclear weapons or devices tested in the atmosphere. Improved versions of neutron, gamma ray, and X-ray detection systems for high-altitude and space surveillance were incorporated into the Launch IV payloads, as was new instrumentation to make sophisticated measurements on background radiation present at 17 Earth-radii distances.

The three pairs of earlier satellites were placed in orbit using ATLAS-AGENA boosters in October, 1963; July, 1964; and July, 1965. In addition to accomplishing their treaty monitoring functions, these satellites have revealed a wealth of new scientific data on the solar wind and its interaction with Earth's magnetosphere.

A fifth launch of twin Earth-oriented satellites is scheduled for late 1968, using a TITAN IIIC booster. The new satellites will have increased capacity for detecting nuclear tests.

DEPARTMENT OF STATE

CHAPTER VI

INTRODUCTION

On January 27, in a ceremony presided over by the President, the Secretary of State and the Ambassador to the United Nations signed the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies."

On October 10, the President presided over a further ceremony marking the entry into force of this Treaty. On this occasion the President noted that: "The spirit of international cooperation that has achieved this agreement is a beacon of hope for the future. It is a credit to all peoples." In the course of his remarks, the President said: "I want to renew, today, America's offer to cooperate fully with any nation that may wish to join forces in this last -- and greatest -- journey of human exploration. Space is a frontier common to all mankind and it should be explored and conquered by humanity acting in concert." The President also said: "The next decade should increasingly become a partnership -- not only between the Soviet Union and America, but among all nations under the sun and stars."

The General Assembly on December 19 unanimously adopted a resolution approving an Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space. The Agreement elaborates rights and obligations of the Outer Space Treaty, among them the duty of signatories to take all possible steps immediately to rescue astronauts in distress and to render them all necessary assistance. Negotiations on this agreement were conducted between the United States and the Soviet Union in close consultation with other members of the UN Outer Space Committee.

Eighty-four countries had signed the Outer Space Treaty and 13 had ratified it as of October 10.

On February 6, at the request of the Soviet Union, the United Nations Conference on Outer Space, which had previously been scheduled for September, 1967, was postponed until August 14-27, 1968. The conference, to be held in Vienna, will emphasize the practical applications and benefits of space programs, with special reference to the needs of developing countries, and opportunities for international cooperation in space activities.

As part of its contribution to the national space program, the State Department continued its efforts to foster international cooperation in the peaceful uses of outer space and foreign support for various aspects of the program, including negotiation of station agreements. It assisted in plans for contingency arrangements for astronaut recovery and continued to take an active part in encouraging broad participation in the development of a commercial global satellite communications system. It also maintained close consultation with other appropriate U. S. agencies regarding possibilities for developing future international cooperative efforts in space science and applications, such as the surveying of Earth resources from satellites.

ACTIVITIES WITHIN THE UNITED NATIONS

As indicated, the Outer Space Treaty has entered into force and the plans for the conference in Vienna in 1968 are under development.

The United Nations Outer Space Committee's Legal Subcommittee laid the groundwork for the agreement on assistance to and return of astronauts and space objects and continues its work on a convention on damages caused by the launching of objects into outer space. The Subcommittee also began a study of problems relating to a possible definition of outer space, and discussed questions relating to various uses of space.

The Technical Subcommittee of the U. N. Outer Space Committee considered matters relating to exchange of information, encouragement of international programs, international sounding rocket facilities, education and training, and definition of outer space. On the question of definition (which had been referred to it by the Legal Subcommittee), it concluded that it was impossible at present to formulate a useful definition of outer space on the basis of scientific or technical criteria.

Outer space was again discussed by the First Committee of the General Assembly between October 17 and October 20. The Committee adopted by acclamation two resolutions, the first requesting the Outer Space Committee to continue its present activities and the second urging the widest possible participation in the U. N. Space Conference. One new activity which the first resolution requested the Outer Space Committee to undertake was a study of the technical feasibility of direct broadcast communications from satellites, as well as the current and foreseeable developments in the field. On November 3 the two First Committee resolutions were adopted without dissent by the General Assembly meeting in plenary session.

TRACKING NETWORKS

Agreements are in existence with the following countries covering the foreign portion of NASA's global tracking network: Australia, Canada, Chile, Ecuador, Malagasy Republic, Mexico, Peru, South Africa, Spain and the United Kingdom. These facilities consist of stations supporting the manned space flight program, a tracking and telemetry network for scientific satellites, and deep-space antennae at four locations around the world. An agreement for a tracking station on Antigua in connection with Project APOLLO was concluded in January, 1967. After a NASA review of its tracking requirements determined that the facilities at Canton Island would no longer be required, the United Kingdom was notified of the intention to terminate use of that station at the end of 1967.

The ESRO (European Space Research Organization) satellite telemetry and command station near Fairbanks, Alaska, was undergoing testing in late 1967 and will be available when ESRO satellites are launched under the terms of a cooperative agreement between ESRO and NASA. This station, manned largely by U. S. contractor personnel, is the first foreign space-tracking station on U. S. soil.

COOPERATION WITH DEPARTMENT OF DEFENSE

During 1967, the Department of State continued to work closely with the Department of Defense on international aspects of the Initial Defense Communications Satellite Program (IDCSP) and the MANNED ORBITING LABORATORY (MOL) Project.

COMMUNICATIONS VIA SATELLITE

Development of the International Telecommunications Satellite Consortium (INTELSAT) global communications satellite system continued at an encouraging pace during the year. By the close of 1967 there were four communications satellites in operational service, providing much-needed telecommunications capacity between North America, Europe and the Far East. A third generation of satellites is expected to be placed into service beginning mid-1968.

Membership in INTELSAT increased from 55 to 60 countries. Six additional countries are to join by the end of this year, and several more are expected to join in 1968. A total of 16 Earth stations were in operational service in various countries of the world by the end of 1967, and authorizations for or actual construction had begun on 15 additional stations. It is predicted that there could be as many as 50 to 60 Earth stations in operation by the end of 1970.

The 1964 agreements which established INTELSAT provide that in 1969 an international conference will be convened to formulate "definitive arrangements" for the organization. In October, Communications Satellite Corp. , the U. S. entity in INTELSAT, submitted a paper to the governing body, the Interim Communications Satellite Committee, proposing organizational structures for this purpose. The basic U. S. proposals were enunciated by the President in his August 14 message to Congress on global communications.

The United States continued active participation in the work of the technical organizations of the International Telecommunication Union (ITU); the International Telegraph and Telephone Consultative Committee (CCITT); and the International Radio Consultative Committee (CCIR). Among important technical problems considered by these groups was the vital matter of sharing the available radio frequency spectrum between satellite and terrestrial facilities.

NATIONAL SCIENCE FOUNDATION

CHAPTER VII

INTRODUCTION

This year as in the past, the contributions made by the National Science Foundation to the Nation's space effort consisted for the most part of support given to basic research projects at colleges, universities, national programs, and national research centers throughout the country. Facilities such as radio telescopes and scientific balloons are also provided by NSF for scientific research related to outer space.

National Radio Astronomy Observatory (West Virginia)

The major facilities of the National Radio Astronomy Observatory at Green Bank, West Virginia, were in heavy demand by visiting astronomers during the past year. Spectral line work on the Hydroxyl radical (OH) and neutral Hydrogen in galactic regions continued to be very active areas of research. The 300-ft. -dia. transit telescope was fully scheduled during the year as was also the 140-ft. -dia. fully steerable precision telescope. The latter instruments served to confirm the existence of recombination lines arising from galactic helium and another element which is believed to be carbon.

The interferometer has been augmented by the addition of a third 85-ft. -dia. paraboloid. High-resolution maps of radio sources have been obtained by this instrument. The 36-ft. -dia. millimeter-wave radio telescope located on Kitt Peak is completed and operational and research programs using it are about to commence upon the conclusion of the calibration procedures.

The Kitt Peak National Observatory (Arizona)

The following reflecting telescopes were in full operation for research in astronomy by visitors and staff members: two 16-inch photometric telescopes, two 36-inch photometric and spectroscopic instruments, a 50-inch remotely controlled telescope which is programmed for photometric work, and an 84-inch general-purpose reflector; also, a long-focus solar telescope of 63-inch aperture, the world's largest. In addition, a program of rocket astronomy is conducted for staff and visitors. During the twelve months ending July 1, more than 80 investigators from 42 U.S. institutions visited the Observatory to use its facilities, as did seven others from six institutions outside this country.

Cerro Tololo Inter-American Observatory (Chile)

Two important events in the development of the Observatory took place during the year. On April 13, in a joint statement at the Punta del Este conference, the

Presidents of the United States and Chile announced plans for a 150-inch general-purpose reflecting telescope for Cerro Tololo. The design of this telescope copies closely the one for Kitt Peak, and significant savings have resulted from combining orders for the mountings and domes for the two instruments. The Ford Foundation will support half the cost of this telescope up to a maximum of $5,000,000.

In November the Observatory was formally dedicated. Four reflecting telescopes ranging from 16 inches to 60 inches in aperture, which have been added to the original 16-inch instrument, came into operation during the year. The President of Chile joined with other U.S. and Chilean government and university representatives and astronomers from both continents in a ceremony of dedication of the Observatory offices at LaSerena and the telescopes and support buildings on Cerro Tololo. An international astrophysical symposium was held at the University of Chile preceding the dedication.

The E. O. Hulburt Center for Space Research at the Naval Research Laboratory (Washington, D. C.)

The NSF continued the support of several university staff members, who proposed astronomical research programs using rockets and satellites, to work with the fine staff and facilities of the Center.

National Center for Atmospheric Research (Colorado)

A number of studies of the Sun and of interplanetary space were conducted at the National Center for Atmospheric Research during FY 1967. For the most part these studies were undertaken at the High Altitude Observatory of NCAR and were designed to increase our understanding of the solar chromosphere, the solar corona, solar activity and the interaction of the solar wind with planetary atmospheres. Outstanding during the year were:

a. Successful observation of the polarization of a coronal emission line throughout the lower corona at the eclipse of November 12, 1966;

b. Combined use of measurements of the white-light corona made photoelectrically (at a field station in Hawaii), from balloons launched from Palestine, Texas, and at natural eclipses to deduce the three-dimensional structure of coronal streamers;

c. Design and initial construction of a satellite-borne coronagraph;

d. Successful mapping of the magnetic fields in a wide variety of solar prominences.

Aeronomy

The Aeronomy Program of the National Science Foundation is involved in a broad spectrum of the space-related sciences. Of significance to the national space science effort has been the program's role in the support of both theoretical and experimental work through approximately 45 active basic research grants during the FY 1967. An example of the type of research activities in the program are contributions made at Harvard to the understanding of the airglow phenomenon in both the Earth's atmosphere and the planet Venus. In conjunction with this research program, there has been developed the only instrument able to measure the 6300 Å line in the dayglow on a routine basis. These experiments are being carried out at the Blue Hill Observatory and relate themselves to the determination of the physical and chemical processes occurring in planetary atmospheres. In support of these research needs the FY 1967 Aeronomy Program contributed to the establishment of airglow facilities at the Universities of Illinois, Pittsburgh, and Michigan.

Solar-Terrestrial Program

The Solar-Terrestrial program supports over 60 research programs, including the continuing data analysis of the IQSY. Although individual programs are often an intensive study of a single part of the solar-terrestrial process, such as the development of a solar flare or the electron precipitation in the auroral zones when taken as a whole, these studies indicate many advances in our understanding about how the Sun interacts with our Earth. Thus, although our measurements must extend out into interplanetary space, the objectives of the study--to understand the solar-terrestrial interaction process--are of interest in understanding our own environment on Earth.

November 12, 1966, Total Solar Eclipse

The scientific results of this eclipse are now available. The NSF through the solar-terrestrial program coordinated more than 300 American scientists who observed this eclipse in South America. NCAR produced a photograph of the white light streamers of exceptional clarity. The well-resolved coronal streamer picture has been used to develop a model for production of these streamers based on magnetic field observations at the solar surface. The magnetic field observations are obtained routinely and may greatly simplify the understanding of the solar corona and solar wind formation.

Infrared observations have suggested that no dust particles can exist closer than 3 solar radii to the Sun. Discovery of this dust-free zone required sensitive detectors at the eclipse. In two separate experiments two experts have reached the conclusion that the dust-free zone extends to 3 solar radii from the Sun.

X-ray observations from thin slices of the solar corona a few hundred kilometers in thickness have been made at Los Alamos. These are the first observations in the X-ray "light" of one atomic species that have been made with high spatial resolution. The striking results are that the emission during totality is very low, indicating that this emission comes from a very thin shell of the solar corona.

Observations of the magnetic field produced by the flow of electrons in the upper atmosphere has indicated a strong response to the solar eclipse. This eclipse was favorable in that the path crossed the equatorial electrojet, as this upper-atmosphere current flow is called. Many other measurements were made to relate changes in the Earth's atmosphere to this turning off of the energy source for a brief time. Ionospheric studies have shown how the electron density changes as the electrons get captured by ions to form a more neutral atmosphere. A natural solar eclipse will remain a valuable occurrence for these upper-atmospheric studies.

IQSY Program

The 73 member nations of this International Years of the Quiet Sun Program planned a final meeting for July, 1967, to summarize the advance in our understanding of the solar-terrestrial processes obtained from the 1964-65 observations. The collisionless shock front or bow shock standing between the Earth and the solar wind, and behind it the magnetosheath of locally turbulent magnetic field, is typical of the new description of Earth's environment that was developed through the IQSY program. The IQSY also included many meteorological observations. Studies of gross circulation of the Earth's atmosphere have been aided by investigations of ozone distribution and high-altitude water vapor concentration made under the IQSY Program. The identification of a helium zone about 500 miles above the Earth has resulted from studies initiated during the IQSY.

Engineering

The Engineering Division supports a number of research programs related to aeronautics and space activities. An example of some engineering research is the work being carried on at University of California. With the assistance of NSF research grants a group at the University of California, Berkeley, has developed a rarefied gas facility of extraordinary flexibility and capacity. This facility was planned with several objectives in view. It is designed to extend the range of current rarefied gas dynamics investigations to lower-density ranges while preserving previous mass flow capability at test-section pressures of 70 to 80 microns. New investigations will be implemented in areas of nearly-free-molecule flows, dilute plasmas, and collision processes. Additionally, it is designed to provide a suitable environment for free molecule testing and for the study of molecular interactions at the surface of the gas phase. Numerous studies are under way on supersonic flow, turbulence, flow of ionized gases and wave dynamics.

Another study on low-density flows is under way at Princeton University. A unique new testing facility was designed, built and put into operation with an NSF Engineering Division grant. This facility for low-density, hypersonic, gas dynamic research uses a graphite heater and nitrogen as a test gas. Using a liquid nitrogen cooled conical nozzle and a test section 12 inches in diameter, Mach numbers of 15 to 22 can be developed with uniform test cores 1 to 4 inches in diameter and 6 to 10 inches long. Satisfactory operation has been obtained for stagnation pressures from 30 to 350 psi at stagnation temperatures from 1,500 to 2,300° K. Studies have been made on flows around flat plates and cones with leading-edge dimensions of less than 0.001 inches. Detailed pressure distributions and flow-field studies were measured using special probes developed during the studies.

U.S. Antarctic Research Program

The U.S. space effort has several ties with Antarctica. Data on the ionosphere and magnetosphere obtainable only in the high latitudes owing to the configuration of the Earth's magnetic field, result from investigations using a 21-mile-long antenna, satellite readout stations, and cosmic rays apparatus. Satellites are also monitored for the space programs of several agencies to help determine the shape of the geoid, refine orbital paths, acquire gravity data, and establish geodetic ties.

Antarctic environmental factors provide useful parallels to those hypothesized for extraterrestrial bodies. The National Aeronautics and Space Administration, with the cooperation of Foundation grantees performing research in the ice-free areas, tests hardware and techniques being developed for space exploration, such as life-detecting samplers and lunar drills. Logistical aspects of the conduct of a research program in a remote and hostile environment have led to a close study of the U. S. programs in Antarctica by several NASA groups.

DEPARTMENT OF COMMERCE

CHAPTER VIII

INTRODUCTION

Four major organizational components of the Department of Commerce contribute to the Nation's space program. The three science and technology bureaus which contribute directly are the National Bureau of Standards, the Environmental Science Services Administration, and the Office of State Technical Services. A fourth bureau, the United States Patent Office, contributes indirectly through its issuance of patents on inventions with space applications.

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

The Environmental Science Services Administration fulfills the Department's responsibility to describe, understand, and predict the state of the atmosphere, the oceans and the space environment, and the size and shape of the Earth. ESSA has five major sub-units which contribute either directly or indirectly to space technology; the National Environmental Satellite Center, the Weather Bureau, the Coast and Geodetic Survey, the Institutes for Environmental Research, and the Environmental Data Service.

Highlights of 1967 -- The Environmental Survey Satellites -- ESSA 4, 5, and 6 -- were launched during 1967 to maintain the operational weather satellite system established in February, 1966. Careful monitoring and control procedures made unnecessary the initially scheduled launch of a fourth satellite.

The Weather Facsimile (WEFAX) experiment aboard NASA's ATS-1 satellite was used to relay processed data from the United States to Pacific area stations. It was also used to receive river stage and rainfall measurements from unmanned remotely located hydrologic stations and to relay these data to the Weather Bureau in Washington, D. C.

Computer-rectified (digitized) mosaics of cloud pictures from meteorological satellites were adopted for daily operational use by the Weather Bureau during 1967. Digitized mosaics of the tropics were sent via the WEFAX experiment from the National Meteorological Center to the Weather Bureau Hurricane Forecast Centers in order to furnish the latest hurricane information with minimum delay.

Satellite tropical storm surveillance was extremely effective during the 1967 season. Eight hurricanes, 29 tropical storms and typhoons in the western Pacific, eight tropical cyclones in the Indian Ocean, and 16 tropical storms and hurricanes in the eastern Pacific were photographed and tracked by ESSA satellites. Warnings sent to the meteorological services of other countries have elicited replies testifying to the timeliness and usefulness of the information.

The operational availability of photographs directly from the ESSA satellites has contributed to international good will, and has resulted in routine use of the photographs for the information of pilots, particularly for flights over long-distance oceanic routes.

Meteorological Satellites

The National Operational Meteorological Satellite System (NOMSS) was maintained during 1967 by the launch of three Environmental Survey Satellites, ESSA 4, 5, and 6. These satellites are furnishing worldwide pictorial coverage of the Earth and its cloud systems daily, except in the areas of polar night. One satellite takes photographs providing global coverage each 24 hours and stores the pictures on board for readout at either of two Command and Data Acquisition stations, one in Alaska and one in Virginia. These data are transferred to the National Meteorological Center in the Washington, D. C., area for immediate use in weather map analysis. The other satellite, through its Automatic Picture Transmission (APT) system, takes and transmits photographs to relatively simple ground stations within radio range of the spacecraft.

Although the ESSA series of satellites fulfills one of the main objectives of the NOMSS, daily observation of global weather conditions, they do not permit nighttime observation of cloud systems or temperature patterns. A new satellite, known in the research and development phase as TIROS M, is under development. The sensors on TIROS M will include a scanning radiometer which will operate in the visible range of the spectrum by day and in the infrared range on the night side of the orbit. This spacecraft also will combine the functions now performed separately by two ESSA satellites, with a consequent saving in costs because fewer launches will be required each year. The launch of the TIROS M R&D spacecraft is planned for the middle of Calendar Year 1969.

Operations of the ESSA Satellites

All of the ESSA satellites were launched into near-polar orbits at average altitudes of 760 nautical miles. The average time for these satellites to orbit the Earth is 114 minutes.

ESSA 3 and 5 are each equipped with two Advanced Vidicon Camera System (AVCS) units; each camera is capable of maintaining global cloud-cover surveillance. The second camera on each spacecraft is held in reserve, thus materially increasing the useful lifetime of the satellites. The pictures from AVCS-equipped satellites are transmitted to ground stations in Alaska and Virginia; relayed to a central processing unit at Suitland, Maryland; processed; and made available to the world meteorological community.

Equipment for ESSA 2 and 4, and now for ESSA 6, is a redundant system consisting of two Automatic Picture Transmission (APT) cameras that take and immediately transmit pictures of the area beneath the satellite to simply equipped ground stations within a 2,000-mile range of the spacecraft. The APT pictures furnish local forecasters with a fresh (3-1/2-minute-old) view of the cloud patterns over or adjacent to the local area. Meteorologists in many countries have begun to place major emphasis on dependable routine receipt of the APT pictures for operational forecasting. Thus the APT-equipped satellites have become an integral part of the

World Weather Watch, an international meteorological observation system now under development. In addition, mosaics covering the United States and adjacent areas are prepared daily from APT pictures received at Suitland. Copies are distributed to the local press and the national news wire services, and are used daily by many newspapers and television stations in the United States.

TIROS VII-X

At the beginning of 1967, TIROS VII-X, the last four satellites of the TIROS series, each had one usable camera. TIROS VII and IX are still being used experimentally after four and one-half and three years, respectively. TIROS VII and X were deactivated on July 1 and 3, respectively. None of these satellites was used operationally during 1967.

NIMBUS II

The APT system of the NIMBUS II R&D satellite, launched by NASA on May 15, 1966, was the only sensor still in operation at the beginning of 1967. This system was used operationally during the periods of minimum usefulness of ESSA 2 and 4, and was especially useful for supplemental observations during the hurricane season of 1967. The data obtained by the other sensor systems of NIMBUS II have been used extensively for meteorological research.

ADVANCED TECHNOLOGY SATELLITE -- ATS-1

ATS-1 was launched by NASA on December 6, 1966. The two experimental systems on board this NASA R&D satellite in which ESSA participates have met and exceeded expectations. The Spin-Scan Cloud Camera can take pictures every 23 minutes. Each of these circular pictures covers almost the entire Pacific Ocean area from Australia to the central United States and views between 60°N and 60°S over the central Pacific.

Digitized Cloud Mosaics

The experimental program to rectify and prepare cloud mosaics by computer, which was started in 1966, has been very successful. Since the beginning of the year, digital mosaics of the entire globe are prepared daily. Sections of these uniquely prepared cloud charts are sent regularly via facsimile to all U. S. stations, and special mosaics of the tropics are sent to the National Hurricane and the Tropical Analysis Centers in Miami. The mosaics are also printed as part of the catalogues of cloud photography to make information more readily accessible to research scientists.

Operational Applications of Satellite Data

During 1967, satellite data were firmly established as an integral part of the daily operations of the Weather Bureau's National Meteorological Center. Numerous operating locations of the civil and military weather services of the United States are also coming to depend on reliable routine receipt of satellite data as a significant source of supplemental information. In outpost areas the pictures from the Automatic Picture Transmission system of the ESSA satellites have become a prime source of data. Airport stations responsible for providing weather information for overseas flights depend heavily upon the pictures for detailed cloud information.

A number of methods for making operational application of meteorological satellite data are in various stages of development and testing. Manuals to train forecasters in the use of satellite data have been developed and distributed to weather installations which receive either APT photographs or facsimile cloud charts. The U. S. Air Force and Navy have described the applications methods developed by ESSA as the basis for training manuals for their own personnel.

The Study of the Geophysical Environment from Space

An interdisciplinary task force composed of ESSA scientists prepared a report during 1967 in which are considered the possible uses of both manned and unmanned space space platforms for obtaining measurements of the physical environment of the Earth. The report emphasizes that single-sensor systems can be used to obtain measurements which satisfy multiple requirements, serving the needs of both the environmental sciences and the Earth resources programs. The report stresses the desirability of a national program for remote sensing in order to avoid costly duplication of development activities and operating space systems.

A committee comprised of individuals representing every scientific discipline within ESSA was formed in May, 1967, to study the utilization of ESSA spacecraft to obtain data useful in meeting ESSA's oceanographic responsibilities. A draft plan for the period FY 1969-1973, proposing the development of capabilities using both orbiting and geostationary satellites was prepared and is under review. Existing or programmed sensors will provide television and infrared data suitable for determining ocean surface temperatures, ocean currents, and the location of sea ice. The use of satellite-interrogated buoys would provide measurements of surface and subsurface parameters such as sea state, salinity, and surface and underwater temperature. New sensors with much higher resolution will have to be developed to provide data usable for such purposes as coastal morphology studies, geomagnetism and geoid investigations, and remote sensing of sea state.

Research and Development Programs of the National Environmental Satellite Center

During 1967 work continued on a number of long-term projects and work on new studies was initiated. Progress in various phases of the work is increasing the understanding of the atmosphere, and improving weather analysis and forecasting. Of particular interest among the more than 50 investigations under way are the following:

a. The Satellite Infrared Spectrometer (SIRS) flight model, developed by ESSA and funded by NASA, will be tested on the NIMBUS B, scheduled for launch by the middle of 1968. This instrument will measure the vertical temperature structure of the atmosphere from satellite altitude.

b. A new instrument, the Infrared Temperature Profile Radiometer, is being developed for test on NIMBUS D. This instrument, an adaptation of the SIRS, has a spatial scan capability designed to provide temperature and humidity profiles when the atmosphere below the satellite is partly cloudy.

c. The Cloud-top Altitude Radiometer, an instrument to measure the height of the clouds below the spacecraft, is under development for use on the first APOLLO flight. These data will be valuable for deducing winds from cloud motion, and for refining the data from the Satellite Infrared Spectrometer and the Infrared Temperature Radiometer.

   These instruments will provide the sensory equipment necessary to improve global observation of weather parameters. The improvements will contribute significantly to the World Weather Watch, a World Meteorological Organization program for which the United States is providing most of the technical leadership.

d. Techniques to measure cloud motions, and hence to obtain good estimates of winds over ocean areas, are being developed through the use of cloud photographs from the ATS-1 satellite. These photographs, taken at 23-minute intervals, provide material for time-lapse motion pictures of clouds over nearly the entire Pacific Ocean.

e. Daily cloud data in digital form are being used to produce time-averaged five-day and monthly cloud charts. These charts are being used in studies of long-period variations in large-scale weather features, particularly those of the tropics.

f. The Satellite Input to Numerical Analysis and Prediction (SINAP) project is making some progress in devising methods for using satellite data as direct input to numerical models. However, most of the productive work during 1967 has been in the development of models of weather patterns and the statistical relationships between meteorological parameters and satellite data.

Washington-Moscow Data Exchange

During 1967, the USSR launched three meteorological satellites: Cosmos 144, 156, and 184, in February, April and October, respectively. In accordance with the 1963 bilateral agreement between the United States and the USSR, satellite data were exchanged over the Washington-Moscow data link established by the agreement. The data from Moscow included satellite nephanalyses (cloud maps), satellite photographs, and solar and terrestrial radiation maps. The peak period of traffic occurred from early June to early August, with a total 1,362 satellite products coming into Washington. By August 20, all data from COSMOS 156 ceased, and it was presumed that the satellite had failed. Data from COSMOS 184 started coming into Washington early in November; they indicate that this satellite is identical with the earlier two.

International Cooperation

The maintenance of the Automatic Picture Transmission (APT) capability of the TIROS Operational Satellite System through 1967 has had a marked impact on international recognition of the United States as a sharer of scientific results in the space program. At the beginning of 1967 approximately 150 ground stations in 45 countries were in operation; by the end of the year over 300 of these stations were in operation and reporting reception of pictures.

The National Environmental Satellite Center provided training and study facilities for World Meteorological Organization, NATO, and AID Fellows from Argentina, Australia, Belgium, Hungary, India, Israel and Poland for periods ranging for one week to six months. Scientists from many other countries also visited NESC for shorter periods during which they were briefed on satellite activities.

COAST AND GEODETIC SURVEY OPERATIONS

The Coast and Geodetic Survey uses satellites operationally in its work in geodesy and precise navigation, and also is engaged in a number of studies to determine the feasibility of using satellite techniques in performing its assigned tasks. The Survey also supports space facilities and activities indirectly through its seismic and geomagnetic activities.

Use of Navigational Satellites

The Coast and Geodetic Survey continues to use the NAVY SATELLITE NAVIGATION System operationally to control ocean surveys. Accuracy of positioning from navigational satellites is considered to be an order of magnitude higher than that obtainable from any other position-fixing system available for deep-sea surveys. Additional equipment has been ordered so that all C&GS Ocean Survey vessels may use this technique.

Geometric Satellite Triangulation

The Geodetic Research Laboratory of the Institute for Earth Sciences worked closely with the Coast and Geodetic Survey to support the worldwide Geometric Satellite Triangulation Program being conducted under cooperative agreements between the Departments of Commerce and Defense and NASA. The Laboratory provided extensive technical and scientific support including the development of long-range and high-precision short-range orbit prediction computer programs, a numerical integration orbit program, research in the application of satellite geodesy and potential theory, and a training program in satellite geodesy.

Field work for the program has continued successfully throughout 1967. There are 13 camera units in the program, including one unit owned by West Germany but operated presently by the German Geodetic Research Institute and the Coast and Geodetic Survey. Four units are operated by the Army Map Service, seven by the Coast and Geodetic Survey, and one by the Military Survey of the United Kingdom and the Coast and Geodetic Survey.

Results of preliminary computations for the stations observed during phase one of the worldwide program are better than had been anticipated. The program at the end of 21 months is on schedule.

Earth Resources Program

The Institute for Earth Sciences' Geodetic Research Laboratory cooperated with NASA in determining the feasibility of applying space technology to the Earth Resources program, including problems of the establishment of geodetic control from precision metric photography acquired in Earth-orbiting satellites and the compilation of small-scale topographic maps from such photography as a fast-response capability to meet cartographic requirements in developing areas.

Time Transmission Tests

The Coast and Geodetic Survey, in conjunction with the National Bureau of Standards and NASA, is testing the ability to transfer time via satellite between two widely separated units. NASA's APPLICATIONS TECHNOLOGY SATELLITE (ATS-2) is being used in these tests to relay VHF time signals to isolated island units. Results of preliminary tests show that the procedure is capable of transferring time within a four-microsecond uncertainty. This method is now being used to transfer timing information to Pitcairn Island in the Pacific.

Photogrammetric Analysis of Satellite Photography

The Coast and Geodetic Survey's Office of Geodesy and Photogrammetry assisted the National Environmental Satellite Center with measurement of cloud movements between sequential photographs made with the spin-scan cloud camera carried by the ATS-1 satellite. C&GS made precise measurements of cloud displacements at several levels, using stereoscopic photogrammetric techniques to obtain cloud movements in vector form.

Activities in Support of the Tsunami Warning System

Rapid means of data relay are needed to improve the operation of the Coast and Geodetic Survey's Seismic Sea-Wave Warning System. The Survey performed an experiment in 1967 in which seismic data similar to those needed for the Warning System were transmitted from Newport, Washington, to Mojave, California, using NASA's ATS-1 satellite.

Seismic Support

The Coast and Geodetic Survey's Seismology Division made a study in 1967 of potential launch hazards for the Rocket Propulsion Laboratory at Edwards AFB, California. Energy releases from controlled detonations using different combinations of rocket propellants, different container configurations, and different modes of launch failure were recorded with seismograph systems to determine an equivalent relationship to a TNT detonation.

Geomagnetism

The Coast and Geodetic Survey has continued to cooperate with NASA in affording use of the large coil systems at ESSA's Fredericksburg (Va.) Geomagnetic Center for testing and calibration of instruments intended for space studies. This facility permits artificial simulation of magnetic fields that would be encountered anywhere on the globe or in space.

Another program on which C&GS is collaborating with NASA is the digitizing of analog records from about 50 worldwide magnetic observatories. Data in this form provide a means for correlation with data from satellites and space probes. Newly developed scaling machines were used to expedite this project.

The Geomagnetism Division of the Coast and Geodetic Survey has also participated in several international projects aimed at improving the analytic description of the main geomagnetic field, which forms a fundamental datum for many space activities. These include instrument calibrations, refinements of analysis techniques, exchange of information and views on cartographic procedures, establishment of new format standards for magnetic charts, progress toward adoption of an International Geomagnetic Reference field, and other aspects of the current World Magnetic Survey Project.

WEATHER BUREAU OPERATIONS

Weather Bureau participation in the space program has expanded significantly during the past year. Experiments are being conducted in data collection from remote platforms via ATS-1 satellite. Specific programs have been established for increased operational utilization of satellite data to improve weather services to the users. The Bureau is also providing greater support to various satellite programs both directly and indirectly.

Experiment with ATS-1 Satellite

The Weather Bureau's Office of Hydrology is using NASA's ATS-1 satellite for an experiment in collecting river stage and rainfall measurements from remote locations. Unattended stations automatically record the river level and accumulated precipitation every 15 minutes. When interrogated via the satellite, they transmit the most recent measurements, together with a station identification code.

Snow Surveying

Under contract efforts and in-house research TIROS and ESSA photographs of the snow cover in the western states are being used in experimental support of the Weather Bureau's River and Flood Forecasting Service. Preliminary results indicate snow surveys can be made for areas as small as 400 sq. miles.

Digitized Cloud Mosaics

Early in 1967, the Weather Bureau initiated an experimental facsimile transmission of digitized cloud mosaics, obtained from National Environmental Satellite Center, to all its forecast offices in the 50 states and Puerto Rico. Due to the very favorable reception at these offices, the program became operational late in 1967. In addition to their use in the preparation of daily forecasts and warnings, the mosaics are reproduced and added to flight documentation for long over-water flights.

Automatic Picture Transmission (APT)

In order to achieve greater economy and efficiency of operation, plans are under way to convert the existing local readouts of satellite cloud data into a central network. Under this plan four stations would supply data to all stations requiring APT data within the contiguous United States.

Meteorological Support

The Space Operations Support Division of the Weather Bureau continued to furnish meteorological services to NASA in support of the manned spaceflight programs. A hurricane and thunderstorm watch was maintained, and daily weather forecasts were provided in support of local activity at Cape Kennedy. Specialized forecasts for component design, testing and evaluation were provided at the Manned Spacecraft Center. Several environmental studies and operational forecasting aids were completed in support of the APOLLO and Post-APOLLO programs. These were used for advance operational and program planning, system design, and facilities development.

The Weather Bureau continued to provide meteorological support to various NASA and DOD facilities supporting the United States space exploration and research effort.

At the NASA Wallops Station (Va.), the Weather Bureau, in addition to the same type of services provided for the DOD facilities, provides meteorological support for aeronautical programs and experiments, such as investigations of sonic boom and noise abatement phenomena, and of aircraft approach procedures.

The Weather Bureau Atmospheric Support Team at NASA's Mississippi Test Facility provides observational support and forecasts of atmospheric profiles for the prediction of sound propagation patterns during the test-firing of SATURN rocket engines.

INSTITUTE FOR TELECOMMUNICATION SCIENCES AND AERONOMY ACTIVITIES

The Institute for Telecommunication Sciences and Aeronomy conducts basic research on the properties of the very high atmosphere, and on the effects of solar activity on communications, and manned and unmanned space exploration. Techniques are being developed for studying and monitoring upper-atmosphere and space disturbances, and the methodology for forecasting the future state of these disturbances is being developed. ITSA activities during 1967 are referred to in the following paragraphs.

Space Environment Monitoring and Forecasting Activities -- Statistical methods, which are expected to improve forecasting reliability, have been developed and are now under test for routine operations. In order to provide direct space measurements to the Space Disturbance Center, two additional sensor systems are planned. The first of these will monitor the flux of solar protons which are injected into the high atmosphere in the polar regions during solar-active periods. A solar proton sensor will be included on the improved TOS satellite series beginning in early 1969. Plans to incorporate solar X-ray sensors, in addition to the proton monitor, on the TOS series have been temporarily deferred in favor of attempting to move more rapidly to a program of X-ray monitoring from a geostationary satellite. Also, additional efforts are under way to make maximum use of the data from the Navy Research Laboratory Solar Radiation (SOLRAD) satellites.

Consideration has been given to the possibility that the space forecasting center can provide service to the NASA APOLLO Telescope Mount (ATM) experiment. This service would provide specialized forecasts of the time and location of each solar-flare occurrence. Such information would enable the astronaut to point high-resolution instrumentation at the given area to study the synoptic development of a flare. Details of such a program are being discussed with NASA.

Ionospheric/Exospheric Studies -- For several years, ITSA has been a major participant in the ISIS (International Satellites for Ionospheric Studies) program. An ionosphere topside sounder was flown on the EXPLORER XX. Data from this satellite and the Canadian ALOUETTE I and ALOUETTE II satellites are used in studies to provide basic understanding of the ionosphere and a number of ionospheric phenomena. This Institute will continue its efforts by participation in the ISIS-A program and other satellites to be launched in this series.

Telecommunication Predictions -- Studies are in progress to develop a method for obtaining a worldwide synoptic view of the ionosphere with use of satellites. In addition to the new geophysical knowledge to be obtained from this approach, the method is designed to yield information that will improve predictions of high-frequency telecommunication circuit performance on a short-term basis. Ionospheric refractive effects will be used to determine ionospheric critical frequencies and total electron density content. This technique will minimize interference and noise which made measurements by other methods more difficult to use. The improved quality of the data obtained by this method should facilitate rapid computer analysis providing "pictures" of the global ionosphere for scientific and telecommunication use. This technique also would provide the capability for probing the entire ionosphere instead of being limited to probing just the top or bottom of the ionosphere.

Rocket Studies -- A program will probe the high atmosphere in the D-region by means of rockets. This will include use of the boosted ARCAS II rocket, with a payload consisting of a proton spectrometer and a Faraday rotation receiver. The spectrometer will provide the height profile and energy spectrum of incoming energetic protons while the Faraday rotation receiver will provide the electron density profile. These data will yield the effective and recombination rates with respect to altitude in order to test theoretical considerations on the formation of the D-layer.

Time and Frequency Dissemination -- Since about July, 1967, ITSA engineers, the Coast and Geodetic Survey and the National Bureau of Standards have cooperated jointly with NASA to determine the feasibility of transmitting time signals by means of geostationary satellites. The NASA ATS-1 satellite transponder was used to provide time signals with an accuracy of about ± 4 microseconds. Such signals will be of use for satellite triangulation measurements and for studies of large-scale geophysical events. The need for cumbersome and expensive transportation of highly accurate and sensitive time standards now employed by the Survey will be eliminated by the adoption of this time dissemination technique.

INSTITUTE FOR OCEANOGRAPHY

The space-oriented activities of the Institute for Oceanography centered on determining the ocean characteristics that could be sensed from spacecraft altitudes, and what oceanographic parameters could be defined by means of the sensed data. The types of sensors that would be required and their sensitivity and resolution capabilities were defined.

The temperature field of the Gulf Stream was measured during a short field project by means of radiometers carried aboard ships and aircraft. The data so obtained were compared with radiation measurement from the NIMBUS satellites.

NATIONAL BUREAU OF STANDARDS

Vital to this Nation's capability for performing advanced and precise technological achievements is the national measurement system. This system includes, among other things, the basic standards for measurement which are in the custody of the National Bureau of Standards, the derived measurement capabilities which stem from these standards, the measurement and instrument developments which permit the application of measurement to specific problems, and the array of measurements of the properties of substances which permit precise and reliable utilization of materials in the design, engineering, and operation of the space effort and other sophisticated technological endeavors. NBS contributes significantly to all aspects of the system in three broad program areas:

Basic Measurements and Standards -- Activity centers around the development and maintenance of a complete, consistent system of physical measurement. The rapid advancement of technology, especially in the field of space, makes it necessary that new standards be developed and existing ones be improved on a continuing basis. Adequate standards of measurement are vitally needed in the production of highly precise equipment used in various critical applications, and in the determination of the performance of components and systems. The measurement of time, for example, can now be made with an accuracy of several parts per million million (10^{12}) -- an accuracy far greater than is required for most applications; however, the critical nature of deep space tracking, communications, and navigation by computer necessitates that time measurement be far more accurate than is required for normal usage. NBS scientists are now working at the forefront of basic physics to develop standards which will meet this vital need.

Materials Measurements and Standards -- These are of particular interest because of the severe limitations imposed by existing materials when such are used for high-speed travel, both within the atmosphere and in space. In dealing with the different environment of space, new and improved materials, equipment, and systems which will perform in an acceptable manner must be developed. Highly pure and well-characterized materials are also of great importance in the space effort; Standard Reference Materials developed at NBS provide urgently needed measurement technology for creating, manufacturing and distributing a wide variety of products vital to the space effort.

Technological Measurements and Standards -- These are used in the application of research. Standards are needed for entire systems, whether they be large computer complexes used to navigate and monitor space exploration, electronic devices to record and analyze the discoveries of outer space, or the total environment within a space capsule, including the human factors which are a real (and difficult to measure) part of space travel. Just as important is the need for developing creativity and inventiveness among the U.S. scientific and technical community, and for disseminating the results of scientific research to a broad audience in order to stimulate the maximum application of research results.

Within these broad areas of research NBS has built up measurement expertise among its scientific staff over the years, and thus is often called upon to perform a wide variety of specialized studies related to aeronautics and space for other agencies of the Federal Government. In fiscal year 1967, over 40 percent of the total NBS budget was provided by outside sources (primarily other Federal agencies), a significant fraction of which was spent in space- or aeronautics-related research.

The following list of activities in primary work areas provides insight into the scope and breadth of NBS activities conducted in support of the U.S. space and aeronautics effort.

1. The basic measurements and standards responsibilities can be divided into:

a. New deadweight force standards.

b. Missile guidance system studies.

c. Air safety improvement through satellite experiments.

d. Review to aid astrophysicists.

e. Ion studies for communications research.

f. Solar radiation use in analyses of space data.

g. Chemicals studies as clues to life in space.

h. Time and frequency research.

i. Adaptation of lasers to space work.

j. High-speed temperature-measuring device.

k. High- and low-temperature measurements.

l. Thermal radiation properties.

m. Vacuum measurements.

2. The standard reference data activity is a coordinated effort to supply the technical community with reliable, carefully evaluated, numerical data which describe accurately the properties and behavior of well-defined substances and materials. The effort maintains both data collection-evaluation centers and a nationwide network of information-data dissemination centers to serve the scientist user.

Data collection and evaluation centers now in existence gather information relating to propulsion, fuel cells, thermodynamic data, chemical kinetics, and materials for use in space vehicles (such as capsules, booster nozzles, guidance systems, communications and in-vehicle computers). There are also major collection-evaluation centers which deal in data relating to the interactions of space vehicles with their surroundings.

3. The scope of materials research includes studies of the properties of oxygen, examination of meteorites, hydrogen slush density reference system, evaluation of rocket use of liquid fluorine, and stress-corrosion cracking of a titanium alloy.

NBS analytical chemists traced the cause of satellite-recorder failures of the NASA-European Space Research Organization program. The failures were due to organic vapors in the "presumed" inert atmosphere of the sealed instruments. The commercial supplier has modified its production procedure. Analysis of the recorders so produced shows marked improvement.

NBS in cooperation with the NASA Goddard Space Flight Center Laboratory provided important data on a number of crystals used in rockets and satellites for measurements of solar X-rays. Goddard personnel were also shown techniques developed for checking the quality of such crystals.

The feasibility of a new type of thermometer, which may measure temperatures down to one one-thousandth of a degree or less above absolute zero, has been predicted mathematically by an NBS physicist and verified experimentally by two scientists at the Ford Scientific Laboratories. Measurement of extreme temperatures is becoming increasingly important because of space travel.

APPLIED TECHNOLOGY

Tapes for Recording Space Data Studied

Much of the investment in equipment, design, construction and launching of space vehicles is lost if the tape recorders collecting data fail to function for the duration of the experiments. NBS has discovered that differences in surface resistivity of tapes used in space experiments cause large static charges to accumulate. This causes high stress during continuous operation of recorders and consequent deformation or breaking of the tapes.

Development of Space Radiation Detectors

NBS has established facilities and procedures for the fabrication and testing of silicon radiation detectors used in space exploration. Special detector devices, not otherwise available, have been developed for solar radiation experiments with sounding rockets.

Clearinghouse Disseminates Space Data

The NBS Clearinghouse for Federal Scientific and Technical Information is the Government focal point for the public dissemination of R&D reports related to space sciences and technology.

Rapid Calibration of Photodetectors

NBS has developed an instrument which rapidly calibrates photodetectors in the visible spectrum. The instrument enables the Bureau to produce photodetector response curves in minutes rather than hours.

Accelerometer Calibration Improved

A recent NBS development has resulted in an improved device for calibrating accelerometers. The improved calibrating device called a "shaker" also has a greater range of use. Accelerometers are widely used in testing mechanical structures such as aircraft wings and rudders.

Testing of Coded Heliport Beacons

In response to a need in the Naval Air Systems Command for some method of studying various sequences of flashing lights for use in coded heliport beacons, a demonstration model beacon was designed and constructed at NBS.

Laser Diode Efficiency and Output Increased

Lasers share at least one problem with electronic components. They get too hot in use for continuous operation. Research on tiny laser diodes at NBS has resulted in a method of applying an aluminum coating that not only reflects light within the diode, but also helps cool it for more efficient operation, and also yields over 50 percent greater output power. The coating is cheap, easy to apply, and can be tested immediately after application.

OFFICE OF STATE TECHNICAL SERVICES

Significant progress was made in 1967 by the Office of State Technical Services (OSTS), Department of Commerce, and the Office of Technology Utilization (OTU), NASA, in carrying out a working agreement established in August, 1966. The purpose of the agreement is to coordinate the complementary responsibilities and objectives of OSTS and OTU in transferring the results of Federally supported research and development to the civilian economy. In this respect, OSTS and OTU exchanged information on their respective plans, policies, and study results; jointly participated in national conferences on information dissemination; and recommended the possible utilization of the NASA Regional Dissemination Centers (RDC's) by the designated agencies and participating institutions as additional resources of information for individual State Technical Services Programs.

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
NATIONAL RESEARCH COUNCIL

CHAPTER IX

INTRODUCTION

The National Academy of Sciences is a private organization of scientists and engineers that serves upon request as an official advisor to the Federal Government. These advisory services are carried out largely by the National Research Council, which was established by the Academy to act as an operating agency.

Within the Research Council, guidance in matters relating to the national space program is provided primarily by the Space Science Board, but the counsel of other units is also made available where aeronautical or space activities relate to their fields of specialization. Among those called upon during 1967 were the Divisions of Behavioral Sciences, Biology and Agriculture, Earth Sciences, and Engineering; the Committee on Atmospheric Sciences; and the Office of Scientific Personnel.

The National Academy of Engineering was established in December, 1964, under the authority of the National Academy of Sciences Act of Incorporation. It is independent and autonomous in its organization and in the election of its members, and shares in the responsibility given the National Academy of Sciences to advise the Federal Government, upon request, in all areas of science and engineering. The aeronautics and space advisory activities of the National Academy of Engineering are carried out by the Aeronautics and Space Engineering Board.

SPACE SCIENCE BOARD

The Space Science Board is a consultative group which, in addition to its governmental responsibilities, furthers space research generally by encouraging discussion of advances and opportunities. Internationally, the Board represents the U. S. scientific community on the Committee on Space Research (COSPAR) of the International Council of Scientific Unions. Much of the Board's attention is given to the longer-range aspects of space science, looking ahead 10 to 25 years to weigh objectives, foresee difficulties that may be encountered, and determine the knowledge, technology and facilities that will be required.

Life Sciences

Two very different branches of the life sciences are involved in space research. One relates to fundamental biological questions--the possibility of extraterrestrial life, the origin and development of life, and the relation between physical properties of our planet (such as gravity) and biological organisms. The other branch concerns manned space flight--the effects of the space environment on man, and the biomedical and bioengineering systems required to sustain him in space, particularly for long periods. The Board's Committee on Life Sciences and its ad hoc panels are naturally concerned with both branches of the field.

Manned Space Flight -- Calendar Year 1967 saw the publication of two studies carried out by Committee groups. Radiobiological Factors in Manned Space Flight (NAS-NRC Pub. 1487) gives the findings of a two-year evaluation of the potential hazards to man of exposure to the natural space radiation environment during flights lasting up to three years. It suggests a scientific and philosophical basis for determining radiation protection criteria for manned space flight operations.

The report reviews pertinent information on radiobiology and identifies those biological responses in man that affect mission success or failure. Interim estimates of dose-response relationships are given where possible, and the factors that may modify responses are described.

The second publication, Physiology in the Space Environment: Respiration (NAS-NRC Pub. 1485B), discusses the probable effects of long-duration space flight on the human respiratory system. The influences of space environmental factors such as acceleration, vibration, prolonged weightlessness, atmospheric pressure, breathing gas, and heat were studied by a small group of specialists participating in the 1966 Woods Hole Study on Cardiovascular and Respiratory Physiology. Objectives of the study were to determine the current state of knowledge of such effects and to identify courses of research and technical developments that should be undertaken in preparation for long-duration missions. The report indicates that no striking effects have been noted in respiratory function in space flight to date, nor is there expectation that the space environment per se will produce debilitating effects during long missions.

A number of other studies carried on during the past year have focused on manned space flight.

The question of purity standards for air and drinking water is important to prolonged flights. Early in 1967 the Board appointed a panel to set air quality standards and chemical, physical, and biological standards for reclaimed water intended for human consumption on spacecraft.

In its report (September, 1967) the Panel extrapolates the Public Health Service purity standards for municipal water supplies to standards suitable for the particular conditions of long-duration space flight, the primary difference being that water used in prolonged space missions will be recycled through the human system many times during the course of the flight, providing occasion for progressive concentration of trace materials and biological organisms. Further recommendations relate to the need for sterilization during the recycling and monitoring of water quality at various stages in the recovery processing.

The assessment of life-support systems for regenerating space cabin atmospheres in a closed cycle has been undertaken by a group composed of life scientists, chemists, and engineers. Studies of space nutrition and waste management on long-duration manned flights have been completed, and an investigation of microbiological problems is getting under way. The potential biological problems of man in a small confined environment will be examined; these include, among other items, the change of non-pathogens to pathogens, alterations of the immunological mechanisms in man, cross-infection, alterations in the mechanisms of infection, and the treatment of infection in space.

An extensive study of the medical, physiological, and behavioral problems related to manned space missions of 100 to 700 days' duration has been initiated at the request of NASA. It is recognized that such missions may involve considerations not encountered to date: the physiological effects of many months of weightlessness and the psychological problems associated with sensory deprivation and confinement may affect crew performance and mission success. It should be possible to derive guidelines for structuring missions so as to avoid or modify adverse effects, to determine those individual characteristics and training most important to mission success, and to single out the research and methodology needed to prepare for and carry out long-term flights.

Physical Sciences

Potential Contamination and Interference from Space Experiments -- From time to time, the possibility arises that a proposed space activity will have adverse effects on the environment or on work in other fields. The Board's Committee on Potential Contamination and Interference from Space Experiments, an interdisciplinary group, attempts to foresee such eventualities, evaluate their likely impact, and, where appropriate, make recommendations to responsible agencies or experimenters.

Studies sponsored by NASA on the concept of large orbiting mirrors to illuminate nighttime portions of the Earth aroused critical comment in the latter half of 1966 and early 1967. At the request of some scientists and also of NASA, the Board asked the Committee to assess the problem. In its report (March, 1967) the Committee concludes that there is no overwhelming evidence that scientific damage would result from the deployment of a single reflector system. But it recommends that such a satellite not be considered in the future unless the ability to destroy it by signal from the ground is an inherent part of the design and unless detailed studies of its effects on ecology, biology, and astronomy are previously conducted and made public. The Committee found no scientific merit for the system commensurate with its costs to the public and its nuisance to science.

The Academy was informed in May that the Government is not interested in the concept at the present time, but that if interest should develop in the future the Academy would be consulted for additional advice.

In response to a request from NASA, all experiments planned by NASA's Office of Space Science and Applications are being reviewed to determine whether they could produce adverse effects or interfere with other studies. The majority of the experiments, which relate to electromagnetic radiation, were referred to the NAS Committee on Radio Frequency Requirements. The Committee concluded that several of the proposed radiations seemed dangerous at first sight but turned out upon investigation to be quite innocuous; nothing on the list was found to cause alarm to the radio astronomy community.

The possible harmful effects of an experiment proposed by the Max Planck Institute in West Germany were also evaluated during the summer of 1967. This experiment, involving the release of barium at five Earth radii, would have no ill effects, the Committee agreed in its report to NASA; on the contrary, since it may trigger an aurora and other scientifically interesting phenomena, scientists should be alerted to the launch date to assure broad participation. NASA has expressed the intention, upon completion of negotiations with the Federal Republic, to announce the program to the scientific community at large and to mount special experiments in the auroral zone and elsewhere to take full advantage of the release.

The possibility of contaminating the Moon or planets with terrestrial organisms adhering to space probes has for some years been a matter of concern to the United States and other nations involved in space research, and thus to COSPAR. Out of this concern has developed a complex technology for the sterilization of spacecraft and their components, and it is a national requirement that all space probes that could contaminate a solar-system body be made as biologically clean as technology permits.

Astronomy -- A long-term evaluation is being made of the scientific advantages and technological feasibility of operating a large telescope in space with manned maintenance. During the past years, specialists in planetary, galactic, and extragalactic astronomy, invited to participate, have helped to isolate problems that can be solved only by such a telescope. After the scientific report is completed at the end of the year, it is intended to examine the design features required to carry out the scientific program and determine the technical problems involved.

International Activities

The Board's international activities are carried out largely within the framework of COSPAR, a consultative organization to which the national space committee of 36 countries adhere and which is advisory to the United Nations.

The Tenth Plenary Meeting of COSPAR was held in London July 24-29, 1967. Sessions covered such topics as the Moon and planets; polar substorms; ionosphere and magnetosphere; collection and detection of interplanetary dust; proton flare projects; aeronomy; and life sciences. Actions taken by the Plenary included revision of the COSPAR Guide to Rocket and Satellite Information and Data Exchange, and recommendations for cooperation with the Global Atmospheric Research Program.

The meetings were attended by about 750 scientists from 47 countries. U. S. participation was organized by the Space Science Board's Committee on International Relations, which also reviewed U. S. contributed papers and prepared the annual report and bibliography on U. S. space research during 1966: United States Space Science Program: Report to COSPAR.

Another international function carried out under the aegis of the Board is the World Data Center-A subcenter for rockets and satellites. The World Data Centers, established in 1957 under the auspices of the International Council of Scientific Unions, collect and archive data from many geophysical sources and experiments. There are three World Data Centers: WDC-A in the United States; WDC-B in the U. S. S. R. and Czechoslovakia; and WDC-C in Western Europe and Japan. Each Center is divided into a number of subcenters representing the major disciplines of geophysics and space research. The rocket and satellite subcenter collects and exchanges results of research conducted with spacecraft and sounding rockets, and makes it available to interested persons on request.

COMMITTEE ON ATMOSPHERIC SCIENCES

The NAS Committee on Atmospheric Sciences examines the current status in the atmospheric sciences in rather broad terms as related to the future needs for research and progress in the field. A major activity for the past two years has been the development of the scientific and technical bases for the Global Atmospheric Research Program (GARP), an international scientific effort designed to achieve by the use of a multiplicity of space- and Earth-based tools a definition of the entire lower atmosphere that will lead to a major advancement in knowledge of the large-scale atmospheric dynamics and thermodynamics. The ultimate aim of the program is to develop an advanced physical and mathematical basis for medium- and long-range weather prediction.

OFFICE OF SCIENTIFIC PERSONNEL

At the request of NASA, the National Academy of Sciences performed the recruiting and scientific selection of the second group of scientists to serve as astronauts in the NASA manned space flight program. Scientific qualifications were set by the Academy. The Office of Scientific Personnel was given administrative responsibility for the program, working in close collaboration with the Space Science Board and the Office of Information.

Approximately 3,000 inquiries about the Scientist-as-Astronaut program were received; of those persons who applied, 923 met the requirements for eligibility and were evaluated by the Board of Selection. A rank-ordered list of 69 recommended candidates was transmitted to NASA in March, 1967; from these nominees, NASA selected 11 new scientist-astronauts. They hold doctorates in astronomy (3), physics (2), geophysics, chemistry, electrical engineering, physiology (2), and medicine.

DIVISION OF BEHAVIORAL SCIENCES

Committee on Hearing, Bioacoustics, and Biomechanics (CHABA)

CHABA panels were active during the year in the fields of sonic boom effects and aircraft noise. Current research at the Stanford Research Institute on subjective response to the sonic boom was evaluated and seven studies recommended to fill the gaps in present knowledge. The progress of research contracts on aircraft noise negotiated by NASA and FAA on the basis of recommendations by a CHABA subcommittee was assessed and further recommendations for directions of research during 1967 were given. A plan to certify aircraft on the basis of noise is under study.

At the request of NASA, the second edition of the Bioastronautics Data Book was evaluated and changes to be incorporated in the third edition were suggested. CHABA is assisting NASA in the selection of authors for the new edition and will act as advisory technical editors.

A meeting on rotational acceleration, sponsored by CHABA and NASA, was held at the U.S. Navy School of Aerospace Medicine in Pensacola, January 24-26, 1967.

Committee on Vision

The Committee has assisted NASA in setting the visual specifications of the visor for the helmet to be worn by APOLLO astronauts. A formal link has been established for the exchange of information between developers of the helmet and visual scientists. In addition, a report was prepared on the "in-house" research on vision being carried out by NASA and the Department of Defense.

DIVISION OF BIOLOGY AND AGRICULTURE

The Committee on Remote Sensing in Agriculture serves in an advisory capacity to those universities and other organizations interested in aerial sensing from aircraft and orbiting satellites of terrestrial soils, plants, and animals. The principal objective of the year has been the preparation of a treatise on Remote Sensing in Agriculture.

DIVISION OF EARTH SCIENCES

NAS-NAE Committee Advisory to ESSA

The NAS-NAE Committee Advisory to the Environmental Science Services Administration reviews general ESSA programs and plans and prepares recommendations. During the past year, panels have been established which include among their topics considerations of the role of satellites in environmental measurement and control. Weather modification, and data handling for weather and oceanographic needs are directly related to ESSA satellite activities.

Committee on Space Programs for Earth Observation

The Committee (COSPEAR/GS) advises the U.S. Geological Survey on remote sensor and spacecraft programs in geology and mineral resources, hydrology and water resources, geography, and cartography. A parent committee and a panel in each of the discipline areas are concerned with both external and in-house research projects set up by the U.S. Geological Survey in collaboration with NASA. A series of studies are under way to determine the applications of scientific data acquired by spacecraft to the Earth sciences.

Committee on Remote Sensing of Environment

The Committee is concerned with the entire field of remote sensing of environment. It has been active in determining the status of sensor technology, in assessing its potential value in research of the Earth's environment, and in providing guidance for development of a stronger national program in this field. The Committee maintains close liaison with other NRC Committees on space and remote sensor programs.

DIVISION OF ENGINEERING

Space Applications Summer Study

The 1967 portion of a study designed to continue for two summers (1967-68) was held under the auspices of the NRC's Division of Engineering. Attended by some 90 specialists from universities, industry, government and other interested NAS-NAE committees, the study treated those aspects of space technology which are likely to produce practical benefits to large segments of the American and world economies, and to increase the well-being of large groups of peoples. Major recommendations relate to research and development, organization and management of space application systems, radio-frequency and data management, use of high-altitude aircraft, and manned versus unmanned space applications systems. An interim report, consisting of several volumes, on the 1967 sessions is to be issued early in 1968.

Materials Advisory Board

The Materials Advisory Board renders advice to the Government on research and development in engineering materials and processes. Although the scope of the Board's interest is very broad, a large portion of its activity during the last ten years has focused on problems with aerospace materials. Two problem areas of major concern are: (1) the extremely high temperatures encountered in turbines, rocket nozzles, and reentry surfaces and (2) the weight factor, which places a premium on materials of high structural efficiency (i. e., highest ratio of strength-to-density and stiffness-to-density).

At the request of the Air Force, three successive MAB groups have made a series of extensive studies to identify the manufacturing techniques and methods that will have to be developed to fabricate structures with the aerospace materials predicted for the 1975-1985 period.

In the broad effort to achieve higher structural efficiency, one MAB committee is currently studying the problems of design with fibrous composites and will report its findings in 1968. At the request of NASA a study is under way on coatings for the protection of graphite, refractory metals, and super-alloys. A current study requested by the Office of Naval Research will define the scientific limitations involved in the development of glasses or other materials usable in high-temperature applications to transmit infrared radiation in the 8-to-14 micron spectrum. Other subjects dealt with in 1967 related to aerospace materials are: ceramic processing for high-temperature use or for such applications as hypersonic flight; beryllium for extremely light but stiff structures; long-range aerospace manufacturing development; and non-destructive techniques for insuring quality control and for monitoring material behavior (i. e., crack initiation) in critical aircraft areas.

COMMITTEE ON SST-SONIC BOOM

The Committee was established in 1964 at the request of the President to "plan an expanded sonic boom program." During the past year sonic boom research and field test experiments were observed at NASA Langley Research Center and at Edwards Air Force Base; the Committee had previously been instrumental in planning some of the experiments. In cooperation with the Department of Agriculture's Beltsville Agricultural Research team, tests on the effects of sonic boom on animals are being developed and the results of previous experiments with farm animals conducted during the Edwards AFB Sonic Boom Phase I test have been evaluated.

AERONAUTICS AND SPACE ENGINEERING BOARD

The National Academy of Engineering established the Aeronautics and Space Engineering Board in May, 1967. The Board is generally patterned after the NAS Space Science Board, but its primary purpose is to focus the talents and energies of the engineering community on significant policy and program issues of concern to NASA and other Federal agencies as they relate to aeronautics and space engineering. The Board will recommend to the Government the priorities that should be assigned to engineering objectives, propose ways to bring engineering talents to bear on aerospace problems of national importance, and suggest methods to improve engineering education in the aerospace field.

For its initial task, with the concurrence of NASA and the indorsement of interested committees of Congress and the National Aeronautics and Space Council, the Board is undertaking a comprehensive study of civil aeronautical research and development. The study is national in scope and is based on a systems approach to the entire civil air transportation problem. The Board intends to (1) critically assess current national policies, plans, programs, funds and organizational structure for civil aeronautical research and development; and (2) recommend steps necessary to insure a viable U. S. civil aviation posture for the future. For the purpose of its study, the Board defines civil aviation to include both commercial and general-aviation types of aircraft. The committee reports will be reviewed and consolidated into an initial Board report planned for mid-1968.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

CHAPTER X

INTRODUCTION

Among the activities of the Observatory this year were the following:

a. Photography of the apogee firing that inserted INTELSAT 2-F2 into synchronous orbit.

b. Installation of prototype laser system in new observatory in Arizona.

c. Combined satellite determination of the gravity field with other gravity measurements.

d. Discovery that the "meteoritic complex" is mutually destructive by collision and is maintained in equilibrium.

e. Confirmed discovery of a new comet.

The Observatory continues to operate a network of stations for the photographic and laser tracking of artificial satellites, several networks for meteor astronomy, laboratories for analysis of meteorites, and other facilities for gathering related data.

OPTICAL SATELLITE TRACKING

Fourteen optical instruments are situated in a network in 11 countries. In addition, 127 volunteer Moonwatch teams maintain observing sites in 22 countries, and 29 teams are available for re-entry patrol.

The Baker-Nunn and modified K-50 cameras provided launch and tracking support for NASA and furnished data for scientific research. Noteworthy among photographic successes was a simultaneous observation by the Baker-Nunn camera at the Tokyo Astronomical Observatory and the cooperating U. S. Air Force Baker-Nunn cameras at Johnston Island, Hawaii, and Rosamund, California. These cameras successfully photographed and confirmed the four-stage apogee motor firing that inserted the INTELSAT 2-F2 satellite into synchronous orbit over the Pacific Ocean.

The Observatory has strengthened its international cooperation in satellite tracking. It entered into an agreement with the National Institute of Geographics of France to exchange observations of French and U. S. satellites. Exchange of precise satellite tracking data with the USSR began in 1967 with the interchange of GEOS flash observations made by the University of Riga and by the SAO Baker-Nunn camera in Spain. There are plans to expand this cooperation to the GEOS-B mission. Also, cooperative observing programs continued with the Western Europe Satellite Tracking network.

The laser tracking system was in operation at the New Mexico station until the end of June. At that time the 1967 coordinated observing schedule with the three French laser stations and the laser station of the Goddard Space Flight Center came to an end. This was the first time a network of laser instruments had been used to track satellites. Then the New Mexico laser station was shut down and prepared for a move to Maui, Hawaii. In 1967, 931 observations were made with this system.

During November an improved laser system was installed in the new observatory on Mount Hopkins, Arizona. Its performance was evaluated as a prototype for laser systems to be established at the other astrophysical observing stations.

A study of the diurnal variation based on the drag of seven satellites in orbit during the years 1958 to 1966 and with perigee heights between 155 and 403 miles confirmed the 1960 suggestion of a diurnal bulge migrating in latitude with the seasons and located at the latitude of the subsolar point. A definite correlation of the amplitude with solar activity could not be established. As a by-product of this analysis, it was discovered that large seasonal variations occur at heights above 310 miles, apparently caused by a variation in the amount of helium in the atmosphere.

Also completed was an analysis of the semiannual variation based on the drag of six satellites during the years 1958 to 1966. All the principal features of the variation described in 1964 were confirmed. The variation is global and caused by a variation in thermospheric temperature. The semiannual and the annual components of the variation repeat in phase year after year; the amplitude is proportional to the degree of solar activity.

Theoretical models of the diurnal variation of the upper atmosphere have been constructed with the use of conductivity and diffusion in three dimensions. Preliminary results are already so close to the observed data that great hope is entertained for future developments of the analysis.

In satellite geodesy the scientific accomplishments of 1967 were built upon the SAO Standard Earth. The general outlook has been toward another comprehensive solution in 1968. This plan involves extension of the gravity field from 8th degree and order to perhaps 12th or 15th degree and order, with miscellaneous higher terms. In addition, the station coordinates should be improved in accuracy, from the 15 meters now available for 12 stations to perhaps 5 to 10 meters for 30 stations. This means the use of data from other observing systems. The processing and integrating of these diverse data types have been progressing.

Supplementary determination of coordinates has been accomplished for several U. S. and European optical stations, and for three stations using the NASA range and range-rate system. These station determinations have been possible through tracking of GEOS-A, the satellite launched by NASA specifically for geodesy.

Satellite determination of the gravity field has been combined with the gravity measurements made by classical methods. In addition, the classical astrogeodetic leveling data and the geoidal heights of the SAO combined geoid have been reduced, giving new values for the datum coordinates and the semimajor axis of the Earth.

METEORITICS

It has been found that the "meteoritic complex" is mutually self-destructive by collisions and is maintained in equilibrium. The gas is removed by solar wind and the tiny particles both by solar light pressure and by light momentum exchange. An influx rate of some 10 tons per second will maintain the system indefinitely. Comets are probably a sufficient source of both this dust and larger particles up to masses of 100 grams. This subject is of wide interest, not only because the dust and small pieces of solid matter in interplanetary space may present a hazard to space vehicles, but also because the procedure for the determination of their natures measures the disintegration rate of the larger comets and asteroids.

Almost 80% of the meteoritic material that falls to the Earth's surface in pieces large enough for mineralogical study contains small, approximately spherical bodies called chondrules. Since meteors are believed to be the remnants of the primordial cloud of matter from which the planets were formed, chondrules represent a very primitive start of the collection of such matter into planets. A solution to the problem of how the first step in the collection occurred was proposed as an effect of heat from electrical discharges (lightning) in the primordial dust cloud. SAO laboratory tests of capacitor discharges similar to lightning in an artificial dust cloud produced particles very similar to the chondrules.

It seems very likely that chondrules of 10 Type II carbonaceous chondrites condensed from or were melted in the primordial gas nebula that predated and gave rise to the planets of the solar system. If so, the chondrule compositions should reflect the composition of the nebula. On this basis, studies indicate that the nebular composition was not the same as the present solar composition. In particular, oxygen was, at least locally, 10 to 20 times more abundant (relative to hydrogen) than it is in the Sun. Localized concentration and subsequent volatilization of oxygen-rich dust grains in the nebula may have been responsible for this.

Studies of material collected from Greenland ice show that Al^{26} and Be^{10} are present in the amounts expected from cosmic-ray interactions with the Earth's atmosphere. However, excess amounts of He^3, Ni, Co, and Ar isotope anomalies indicate that some cosmic dust is present in the ice. This combination of results indicates that the cosmic dust was imbedded in fragile chunks of cometary material in space.

Experimental efforts in the SAO metallurgical laboratory during 1967 were directed primarily toward metallographic examination of samples of iron meteorites; the study of the crystallography of iron meteorites by X-ray methods; and experimental work to evaluate the effects of very high hydrostatic pressure on the speed of response of a laboratory alloy to heat treatment.

The Prairie Network has continued the now-routine photographic observation of exceptionally bright meteor events. New data have confirmed the earlier conclusions that the great majority of meteors - even those brighter than full Moon - are produced by material of low structural integrity and, very probably, of density much less than that of meteoritic stone. An important corollary being investigated is that some of the more massive objects do not suffer complete ablation or fragmentation in the atmosphere. It is likely that some terminal masses, in the kilogram range, reach the ground intact. Ground search for this new extraterrestrial material, which may possibly have its origin in comets, may be successful in those cases where the impact point can be determined with reasonable accuracy.

An analysis of radar echo characteristics from meteor trails was made by the Radio Meteor Project. It established the nature of the radar return and yielded data on observational selection effects. These effects are of critical importance in the evaluation of the basic meteor data for meteor astronomy and the physics of the meteor process, and of the impact hazard to astronauts and space vehicles.

COMETARY STUDIES

On July 3 the astrophysical observing station in Australia confirmed the discovery of the new comet, Mitchell-Jones-Gerber (1967d). The Baker-Nunn network routinely photographs all comets within its optical capabilities and immediately reports comet positions to the International Astronomical Union Central Telegraph Bureau. The data received are used to update individual comet orbits for continued observations.

A study has been made of the group of Sun-grazing comets, of which Comet Ikeya-Seki, widely observed in the autumn of 1965, is a member. It appears that there are two definite subgroups, the members of each having separated from each other during their last two or three revolutions about the Sun. The two subgroups themselves represent similar separations some 10 to 20 revolutions (7,500 to 15,000 years) ago.

The orbits of many of the short-period comets are also being investigated. More light has been shed on the nongravitational forces claimed to be acting on these comets. The forces acting on the diffuse, dusty comets are very much larger than those acting on comets that appear to have lost the greater part of their dust.

GAMMA-RAY ASTRONOMY

A vidicon spark chamber was flown in a high-altitude balloon to search for cosmic gamma radiation with energy greater than 100 million electron volts. No radiation from specific celestial sources was detected; however, a new upper limit to the flux from the Crab Nebula was established. A solar flare (type 2) also occurred during the flight, but no gamma radiation was detected.

A large optical reflector, 34 feet in diameter, designed to detect the Cerenkov radiation produced in the night sky by cosmic gamma rays in the 10^{11} to 10^{12} electron volt region, is being built for operation in the spring of 1968. The instrument is located on the 7,600-foot level of Mount Hopkins, Arizona.

LUNAR AND PLANETARY STUDIES

Consideration of the deep-space vacuum surrounding the Moon and measurements of surface materials by SURVEYOR and LUNA landings, as well as microwave thermal observations, are consistent with a lunar surface free from liquid water to a considerable depth. Such dry surface material of basalt or other rocks similar to those in the Earth's crust should be transparent to radio waves, particularly of longer wavelengths. The Moon may thus form a spherical radio lens. Tests of this idea can be made by means of transmitters on Earth and a circumlunar satellite containing appropriate receivers. A successful conclusion of such tests will determine how to communicate between lunar landing parties; the lunar crust might be used as the ionosphere is used on Earth.

The remarkably clear photographs taken by NASA's five lunar orbiters show features that raise the curious possibility that water may once have existed on the surface of the Moon. Hundreds of meandering lunar valleys that probably once contained rivers that drained into the drying seas were left as the water either evaporated into space or sank back into the cooling lunar interior. If it once had water, the Moon must also once have possessed an atmosphere. This atmosphere would not have disappeared into space as rapidly as once thought. It could have persisted for upward of 100 million years.

Investigation of the planet Venus has led to the suggestion that the radio emission from that planet may be from its surface. Surface temperatures varying over the disc between 400 and 900°K were predicted, along with surface pressures of some tens of bars. It was also concluded that the high surface temperatures can be explained by an atmospheric greenhouse effect, provided the atmosphere of Venus contains a few tenths of a percent of water vapor. In this case, the clouds of Venus must be composed at least in part of ice crystals. All these predictions were apparently confirmed by the capsule from the Soviet VENUS 4 space vehicle, which reported a nightside temperature of about 550°K, a pressure of about 22 bars, and a few tenths of a percent of water vapor in the atmosphere.

The Martian surface may be composed in significant part of the mineral geothite, a hydrated iron oxide similar to rust. The particle sizes in the dark areas of Mars are larger than those in the bright areas, and the seasonal changes appear to be due to changes in the particle size rather than in the composition of the dark areas. A theoretical discussion shows that dust storms on Mars may be frequent and that the annual exchange of fine-dust particles between highlands and lowlands may account for the seasonal and other changes previously attributed to life on Mars. Such an analysis in no way excludes life on Mars; it merely underscores the difficulty in detecting life on Mars over very great distances.

Another telescopic observation of Mars shows that its atmosphere is composed almost entirely of carbon dioxide and that the total atmospheric pressure is about 6/1,000 that on the Earth. This observation was made with an interferometer of high spectral resolution.

The radio emission from Mercury may be understood in terms of the orbital geometry of Mercury and a lunar-type surface.

Theoretical and laboratory investigations of Jupiter suggest that complex organic molecules may be being produced there at significant rates by electrical discharges and solar ultraviolet radiation.

DEPARTMENT OF TRANSPORTATION

CHAPTER XI

INTRODUCTION

The Department of Transportation was created by the Department of Transportation Act of 1966 (approved October 15), and began operations on April 1, 1967. On the latter date the Federal Aviation Agency became a major component of the new Department as the Federal Aviation Administration. All aeronautics activities of the Department appropriate to this report fall within the missions of FAA, and center on insuring safe and efficient utilization of the Nation's airspace and otherwise fostering civil aeronautics and air commerce.

During 1967, both airline transport and general aviation continued their remarkable growth trend of recent years. To keep pace with the resultant increase in responsibilities, the FAA continued to pursue or sponsor a variety of aeronautical research and development programs.

AVIATION SAFETY RESEARCH AND DEVELOPMENT

FAA's primary mission is to insure aviation safety. R&D programs having this special objective during the year aimed at: making the aircraft a safer vehicle, in flight and in crash landings; widening the safety margin for operations on or in the vicinity of airports; and making better accommodation for human factors involved in safety.

In-Flight Safety

R&D efforts aimed at improving in-flight safety of aircraft sought better ways of dealing with the following causes of accidents:

a. Engine fire. Tests that had been in progress for the past two years on protection of powerplant installation in current four-engine air transports were completed, and the final report will be issued early in Calendar 1968.

b. Lightning strikes. During the years the final report was issued on a program that investigated characteristics of natural lightning by triggering lightning strikes on a specially equipped research ship (17 such strikes were triggered in the summer of 1966). Final reports were also issued on fuel-air mixtures in aircraft fuel tanks under flight conditions, and lightning hazards to aircraft fuel-system vents.

c. Unexpected stall or spin. In response to the continued large number of fatal stall-spin accidents in general-aviation flying, FAA initiated a comprehensive study to find the most effective type of indicator to warn light-aircraft pilots of airspeed decline toward the point where stall-spin will result. The project is scheduled to be completed during Fiscal 1968.

d. Light-plane design characteristics. In a cooperative effort with the Civil Aeronautics Board, FAA used statistical analysis to investigate those features of light-plane design that might have increased the probability of pilot error in accidents; the final report on this project was issued in Calendar 1967.

e. Training for general-aviation pilots. Improved training curricula and more effective methods of testing applicants for private pilot certification are expected to result from a survey being made to determine actual patterns of flights in local and cross-country general aviation flying. Another project is developing a curriculum that incorporates training for instrument ratings with training for the private pilot's certificate, in an effort to encourage qualification for instrument ratings at the earliest stage of the pilot's flying career.

f. Mid-air collisions between aircraft. FAA's R&D efforts on this problem during 1967 were marked by: (1) participation in Government-industry conferences to develop national standards for components of one type of airborne collision-avoidance system that may be operating in future civil-military systems of airborne-collision prevention and air navigation and traffic control; and (2) conducting of over-ocean flight tests of three types of equipment for measuring aircraft-to-aircraft distance as part of a separation-assurance system (tests thus far indicate a useful operational potential in such equipment to assist in reducing over-ocean lateral separation standards).

g. Aircraft sabotage. In its continuous effort to find a solution to this safety problem in the operation of civil transport aircraft, FAA has had for the past several years a program aimed at developing a chemosensing technique for detecting concealed explosives.

h. Hazardous weather conditions. The magnitude of this problem is reflected in losses to scheduled air carriers exceeding $20 million during the last five years as a result of accidents caused by extreme turbulence, hail, or lightning. Turbulence is most often associated with thunderstorms and line squalls but may, infrequently, be encountered in clear air. During 1967, FAA (1) continued, in cooperation with the Environmental Science Services Administration, the development of radar techniques for detecting hazardous storms (one such technique already developed is Doppler-radar mapping of gust velocities) and preparation of guides to assist air traffic controllers and pilots in correctly interpreting the data presented by such techniques on their radarscopes; (2) collected reports resulting from completed testing of an infrared detector that is undergoing privately financed development; (3) continued to serve on the National Committee on Clear Air Turbulence until completion of the committee's final report and the committee's dissolution; and (4) began participation in formulating a Federal clean air turbulence plan.

i. Aircraft wake turbulence. Turbulence in the wake of a large aircraft can be a hazard to smaller aircraft under certain conditions. FAA's R&D effort in this area is aimed at: (1) categorizing the vortex flow behind the aircraft, (2) determining effect on encountering aircraft, and (3) seeking a practical solution. Work accomplished in 1967 included compilation of data on the size and strength of vortexes and examination of vortex motion and decay.

Postcrash Safety

To increase the safety of aircraft following crash landings, FAA aimed R&D efforts at:

a. Better fuel containment. Improved bladder cells and quick-closing valves, designed to resist fuel spillage under survivable crash conditions, were being tested in typical large-aircraft tanks; improved integral fuel tanks designed to meet the same conditions were also being tested. This program is scheduled to be completed in Fiscal 1969.

b. Development of standards for aircraft-cabin interior materials. Such materials, including those in current use and new materials proposed for use in transport aircraft, are continuously being tested to determine their flammability and their smoke and toxic-gas characteristics; during 1967, 150 materials were tested and reported on.

c. Quicker emergency evacuation of aircraft cabins. Following a feasibility study conducted in Calendar 1966, design of an emergency exist system using explosive techniques was under way in Calendar 1967, with full-scale testing of the concept scheduled for Fiscal 1968.

d. Prevention of postcrash catastrophic fires through thickened fuels. Continuing work under way for several years, FAA in Calendar 1967 sought to establish a rating system for controlling flammable fuels; a J47 aircraft engine (a jet type) was successfully operated on gelled fuels. In over 100 tests, FAA investigated burning characteristics of different types of modified fuels under impact conditions; work will begin early in Calendar 1968 toward determining the compatibility of thickened fuels with the entire fuel system of a typical four-engine jet aircraft. A major milestone in this research will be full-scale crash tests of controlled-flammability fuels in Fiscal 1969.

e. Incorporation of greater crash survivability in aircraft design. During Calendar 1967, an analytical computer technique was developed that can be used to predict fuselage behavior under stresses of a crash. Scale-model tests in this area of research are scheduled for Fiscal 1968.

Airport Safety

Notable problems affecting operational safety of aircraft at or in the vicinity of airports and FAA's efforts in 1967 for better solutions included:

a. Snow removal. An engineering requirement for airport snow removal was developed, and negotiations were begun with the U. S. Air Force and the Royal Canadian Air Force for cooperation in carrying this work forward.

b. Runway slush measurement. Available techniques were analyzed in a final report, which concluded that application of these techniques to civil airports is not feasible.

c. Efficacy of airport firefighting equipment and techniques. Dry chemicals and foams were evaluated and adequate fire protection was defined in terms of discharge rates, total quantities, and types of agents.

d. Short-of-runway landings. Criteria were developed for an airport impression fence, a safety device to minimize landing in the undershoot area.

e. Bird hazards. A contractor's report was issued with recommendations for reducing the hazard of aircraft collision with birds in or near airports.

f. Runway traction under wet and slippery conditions. Previous FAA experimentation having indicated that such traction would be improved by grooving of runways, the agency continued experimentation in 1967 to determine optimum groove patterns, beginning surface tests of 18 groove patterns; completion is scheduled for Fiscal 1969. The principal runway at Washington National Airport was grooved during Calendar 1967.

Aeromedical Research in Aviation Safety

The above-described efforts were complemented by an approach through aeromedical research to many aviation safety problems, including:

a. Post-crash smoke and fire. In 1966 the agency developed a polyamide hood with aluminum coating to protect individual passengers in a crashed aircraft against inhalation of smoke or noxious gases, damage to vision, or head burns. In Calendar 1967 FAA developed a prototype hood and tested it on typical passengers.

b. Emergency escape from large aircraft. Human responses to improved emergency equipment (slides, exit design) are being determined in relation to seating capacities of jumbo jets and SST's, in a program started in 1966 and scheduled for completion in 1969.

c. Human body tolerances to impact. Continuing work begun in 1965, this program during 1967 added information on tolerances at a number of points on the human head, chest, abdomen, and limbs. Resulting data are to be used by aircraft designers for modifying aircraft instrument panels and seat backs so that they are less dangerous to passengers on impact.

d. Cosmic rays at SST altitudes. A program begun in 1966 seeks to assess the cosmic-ray environment to which SST passengers will be exposed. In 1967, special measurements of cosmic-ray parameters were made from B-57 aircraft at SST altitudes.

e. Crop-dusting pilot exposure to pesticides. To guide preventive measures, FAA is studying effects of convulsant pesticides on specific parts of the nervous system; in 1967, centers of the brain most directly affected by certain crop-dusting or crop-spraying chemicals were localized.

f. Work-rest scheduling for U.S. Forest Service pilots. Data from physiological assessment of pilots before, during, and after long flights combating actual fires have been turned over to the Forest Service to help guide effective use of pilots in emergencies.

AIRSPACE USE AND CONTROL

The continuing efforts to modernize the air traffic control subsystem of the National Airspace System (NAS) apply in two general areas: en-route and terminal. En-route aircraft flying under instrument flight rules (IFR) are controlled by air route traffic-control centers (ARTCC's). Aircraft departing from or preparing to land at airports (terminals) are controlled by airport traffic-control towers. For control of aircraft in both the en-route and terminal phases of flight, modernization involves substantial automation of the processes by which the centers and towers receive initially and keep current the information (such as aircraft identity, altitude, and flight-plan progress) needed to control air traffic within their jurisdictions.

Modernization of Air Traffic Control at Centers

Modernization of the en-route phase of air-traffic control involved during 1967, as it did in 1966, steps to provide interim relief in the congested New York City area, and further progress on the first field installation of the NAS En Route Stage A advanced-design equipment at the Jacksonville (Fla.) ARTCC.

At the New York ARTCC, a configuration called NYCBAN (New York Center beacon alphanumerics) was constructed with the aid of the experience and knowledge gained from the SPAN (stored-program alphanumerics) field appraisal, described in earlier reports, and the actual hardware and software from the SPAN configuration. NYCBAN is in limited operation. Its functional capabilities, appraised against probably the most difficult radar beacon and traffic control environment in the United States, have revealed deficiencies that must be corrected before the configuration can be of maximum usefulness. Work on the necessary improvements began in the latter part of 1967.

At the Jacksonville ARTCC, site preparation for installing the NAS En Route Stage A Subsystem was completed, all major hardware items were installed, and initial testing was conducted. A system integration and checkout plan for hardware integration, computer program, system shakedown testing, and operational changeover was prepared. System testing will take place over the next year.

Elements of the NAS En Route Stage A Subsystem will be thoroughly tested in a "test" environment at FAA's National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N.J., before operational use in the "live" field facility at Jacksonville. For this purpose, a System Support Facility and a NAS Control Office were established at NAFEC. All hardware for the System Support Facility was installed and accepted, and hardware integration was virtually completed.

Contract commitments were made for all the major hardware for the entire Stage A program following Jacksonville. Installation of the Stage A Subsystem at the various other ARTCC's (and thus automation of en-route air-traffic control) across the contiguous United States is expected to be completed in the early 1970's.

Modernization of Air Traffic Control at Terminals

The system description was completed for TRACON M, the terminal radar approach control system for major metropolitan terminal complexes. This system will in large part use hardware components of the NAS En Route Stage A Subsystem.

The TRACON M program, however, was placed in abeyance during the year, and resources were redeployed to the more general problem of air-traffic control at medium-density terminals. Description and specifications were completed for a beacon-tracking modular and expandable system that will include functional capability required at medium-density terminals, and a request for proposals from industry was issued. For lower-density terminals equipped with beacons, the DAIR (direct altitude and identity readout) configuration (described in the 1966 report) has been designed; during 1967, a joint civil-military contract was negotiated for development and production of a DAIR prototype.

Subject to availability of funds, test and evaluation of the basic DAIR prototype is scheduled for completion in Calendar 1968. Similarly, the first equipment of the beacon-tracking system mentioned above is scheduled for installation at a major terminal in 1969, with follow-on installation at 61 field locations by 1972.

OTHER PROGRAMS FOSTERING CIVIL AERONAUTICS

The Civil Supersonic Transport Program

During 1967 the highlight of the Government-industry effort to build a U. S. civil supersonic transport aircraft was President Johnson's decision, announced April 29, to proceed with Phase III, the prototype development phase. This decision was based on the recommendation of the President's Advisory Committee on Supersonic Transport. Phase II, the design competition phase, ended December 31, 1966.

On May 1 FAA, which has been managing the SST development program on behalf of the Government, signed with the winner of the airframe-design competition and the winner of the engine-design competition contracts calling for development of two identical SST prototypes. Both contracts were made retroactive to January 1. Under their terms the Government will contribute 90 percent of all normal "allowable" costs, and the manufacturers, 10 percent. The manufacturers' share will rise to 25 percent in case of any "allowable" overruns above a specified contract amount, with the Government's share shrinking to 75 percent. The manufacturers must bear all costs which, though normal in commercial programs, are "non-allowable" under Federal Procurement Regulations. Under a royalty plan in the contracts, the Government will recover its investment in the program by about the sale of the 300th aircraft, plus a share of sales above 300.

Other developments in the SST program included:

a. Announcement, in late April, that 10 U. S. air carriers had agreed to financing the prototype program. This was to be done through contributions of a million dollars in risk capital for each delivery position held on the SST reservation schedule. The resulting investment of $52 million will be used for program expenses in Fiscal 1968 in lieu of Government funds that otherwise would have had to be appropriated.

b. Announcement, in June, that the airframe contractor had agreed to take over from FAA responsibility for allocating SST delivery positions to purchasers. The same announcement stated that the contractor will require a deposit of $750,000 in risk capital for each new delivery position, these funds to be applied to the program in lieu of Government funds. These deposits will bear no interest but will be subject to recovery by the airlines through the royalty agreement in the prototype development contract.

All-Weather Landing Systems (AWLS)

The ultimate goal of an all-weather landing system is to make aircraft operations independent of visibility conditions caused by weather. R&D work toward that goal takes place in three technical areas: (1) the electronic ground-based subsystem which emits guidance signals pertaining to an aircraft's angle of descent, deviation from alignment with the runway centerline, and distance from runway touchdown; (2) the airborne subsystem, which includes guidance displays (from the signals), fail-safe monitors to inform the pilot how the subsystem is functioning, automatic devices and flight-control systems to relieve the pilot of some of the work of landing, and an override capability for manual operation of automatic flight controls; and (3) the airport guidance subsystem, which includes lights or other devices capable of providing guidance to aircraft under low-visibility conditions from touchdown to ramp. A perfected AWLS must integrate equipment developed in these three technical areas. Subject to availability of funds, a limited all-weather guidance system is scheduled for completion by the end of 1969.

Progress in 1967 included:

a. In the electronic ground-based subsystem: procurement and satisfactory testing of developmental hardware for the first phase of this subsystem, including such major components as localizer, glide slope, marker beacon, precision distance measuring (DME), system test, and monitor indicators and control equipments.

b. In the airborne subsystem: flight tests and simulation experiments that produced conclusive data on the configuration of airborne equipment necessary for the high degree of reliability this type of operation requires, though further development and testing is necessary to refine some of the elements found inadequate.

c. In the airport lighting subsystem: performance of fog-chamber tests and analyses of airport lighting under low-visibility approach, landing, and taxiing conditions; award of a development contract for high-intensity flush flashers (i. e., flashing lights flush with the runway) for displaced thresholds.

Other Projects

Progress was also made in Calendar 1967 on the following:

a. Area navigation. Several types of area navigation, developed to overcome the radial-flying limitation, were tested with satisfactory results.

b. "Self-contained" navigation. Inertial "self-contained" navigation systems are recognized as a requirement in both subsonic and supersonic aircraft. During the year, transoceanic flight tests on a worldwide basis were completed. In November, the first domestic cross-country jet flight using dual inertial navigators was completed.

c. Simulation studies of SST operations. Conclusions were: (1) One-way tracks should be provided for quick descent of SST aircraft to lower altitudes in non-radar environments, and (2) vectoring or rerouting of subsonic aircraft will occasionally be necessary to get them out of the way of straight-route unrestricted SST transoceanic acceleration.

d. Long-range air-ground radio-frequency systems. In a project aimed at improving communications between ground stations and aircraft flying ocean routes, a high-gain system consisting of VHF and UHF transmitters was installed in Hawaii and achieved communication with aircraft at ranges up to 600 nautical miles on VHF and 550 nautical miles on UHF. A moderate-gain system was installed at NAFEC for further experimentation.

e. Large-screen display of air traffic control data (Eidophor). The Eidophor is equipment permitting large-screen display of radar targets (aircraft) for viewing by controllers and supervisory personnel controlling air traffic in congested areas. In October, the Eidophor was installed in a facility for centralizing radar control of air traffic in the New York metropolitan airspace.

FEDERAL COMMUNICATIONS COMMISSION

CHAPTER XII

INTRODUCTION

The global communications satellite system continued to expand during 1967, as additional countries joined the International Telecommunications Satellite Consortium, additional satellites were launched, and new Earth terminal stations were in various stages of planning and construction in many parts of the world. As of December 31, 1967, 60 countries had become members of the International Telecommunications Satellite Consortium. Two satellites were placed in orbit over the Pacific and an additional satellite was placed in orbit over the Atlantic. Additional Earth terminal stations are being built in the United States and Europe, and new stations are being constructed or planned in Mexico, Central and South America, Africa and Asia.

REGULATORY ACTIVITIES

The Commission on June 2, 1967, granted authority to the Communications Satellite Corporation (ComSat), American Telephone and Telegraph Company (AT&T), ITT World Communications Inc. (ITT Worldcom), RCA Communications, Inc. (RCAC), and Western Union International, Inc. (WUI), to construct a communications satellite Earth station near Rowlesburg, West Virginia, to provide communication services between the U. S. mainland and Europe, South America, Africa, and other Atlantic and Caribbean locations. On June 19, 1967, authority was granted to the same communications companies to construct a communications satellite Earth station near Jamesburg, California, to supply communication services between the U. S. mainland and South America, Hawaii, and other points in the Pacific.

On July 20, 1967, the Commission authorized ComSat, ITT Cable and Radio Inc. - Puerto Rico, ITT Worldcom, RCAC and WUI to construct a communications satellite Earth station near Cayey, Puerto Rico. It is intended to provide communication services between Puerto Rico and the U. S. mainland, South America, Europe, and other Atlantic area locations.

The foregoing station facilities were authorized pursuant to an interim joint Earth-station ownership policy recently established by the Commission under which ComSat and common carriers in international service would be jointly licensed for U. S. Earth stations. These new stations, together with the existing stations at Andover, Maine, Brewster Flat, Washington, and Paumalu, Hawaii, will be operated by the joint licensees with the global communications satellite system contemplated by the Communications Satellite Act of 1962. Services include multi-channel telephony, telegraph, facsimile, high-speed data, and both color and monochrome television.

The Commission authorized ComSat to participate with its partners in the Telecommunications Satellite Consortium (INTELSAT) in the commercial operation of four satellites during 1967.

The Commission's Notice of Inquiry, instituted March 3, 1966, relating to the possible use of communication satellites for domestic use, was extended, on the application of one of the parties, to permit filing of additional comments by September 18, 1967. A total of 34 companies, associations or individuals have filed comments or reply comments in the Notice of Inquiry.

FREQUENCY-SHARING CRITERIA AND INTERNATIONAL COORDINATION OF FREQUENCY USAGE

In order to permit communication satellite service to share the use of certain microwave bands employed by terrestrial services, internationally agreed-upon sharing criteria were evolved and adopted domestically in the Commission's rules in the form of various technical limitations applicable to the non-government space services. This interference protection is based on power limitations, permissible angles of elevation for Earth-station antennas, geographic separation of stations in the sharing service and the coordination of proposed frequency assignments.

These criteria are being studied continuously with the aim of further refining them. Increased attention is being given to the potentially serious problems of off-path scatter interference. Commission staff members are participating in this and other work as members of the preparatory committee on U. S. Study Group IV of the International Radio Consultative Committee (CCIR). The CCIR is under the aegis of the International Telecommunication Union (ITU), for which it conducts studies and makes recommendations on radio technical matters. The next international meeting of Study Group IV is scheduled to convene in Geneva September 18 - October 8, 1968.

At the request of INTELSAT, the Commission coordinates with all administrations representing parties to the Interim Agreement the proposed frequency usage and physical deployment of INTELSAT satellites to be used in the global communication satellite system. Following general agreement on the frequencies to be employed in the space segment of the system, the Commission notifies the International Frequency Registration Board (IFRB) of the International Telecommunication Union (ITU), on behalf of all concurring administrations, so that the ITU can enter the information in its Master International Frequency Register.

AERONAUTICAL DEVELOPMENT

The Commission, in discharging its statutory responsibilities with respect to non-government uses of radio for aviation, prescribes the manner and conditions under which frequencies may be assigned for aeronautical telecommunications. This includes flight-test telecommunications and telemetry functions used in the development and production of missiles, rockets, and satellites as well as aircraft. In addition the Commission assigns frequencies to aircraft radio stations, aeronautical enroute, radionavigation, aeronautical advisory, and other stations comprising the aviation radio services.

Commission staff representatives have continued working nationally with other government agencies and the aviation industry, and internationally with the International Civil Aviation Organization (ICAO), towards the development of system parameters and the application of space radiocommunication techniques to help satisfy the communication requirements of domestic and international civil aviation.

The air transport industry, under the authorization of the Commission, continued during 1967 tests begun in 1966 to assess the relative merits of AM versus FM emission techniques and normal power versus substantially higher power aboard aircraft as elements between a communication aeronautical station and aircraft via satellite. The Commission staff continued study of the results of the continuing test programs and of techniques to be used in aeronautical satellite communications.

The Commission staff representatives have participated in the preparation of material submitted by the United States Delegation to the various International Civil Aviation Organization (ICAO) Meetings.

The Commission authorized Aeronautical Radio, Inc., and various scheduled airlines to participate in tests using NASA's APPLICATIONS TECHNOLOGY SATELLITE (ATS). During 1967, tests using the ATS were continued. Satisfactory communications were exchanged, relayed via satellite, between ground terminals and aircraft in the Pacific. Results of these tests are being studied by the Commission staff. An additional test program using a different ATS over the Atlantic was in progress at year's end.

Commission representatives are helping to prepare for the forthcoming ICAO Limited European/Mediterranean (EUM) RAC/Com (VHF) Meeting in Paris during the first quarter of 1968, which will treat aeronautical satellite systems. It is also participating in the U. S. position and documentation for the Ad Hoc Group on aeronautical satellite matters of the Interim Communications Satellite Committee of INTELSAT.

SPACE TECHNIQUES FOR THE MARITIME MOBILE SERVICE

The Commission, working with the Inter-Governmental Maritime Consultative Organization (IMCO), the International Radio Consultative Committee (CCIR), ComSat, industry and other government agencies, is studying the potential value of adapting satellite relay techniques to the communications requirements of the maritime mobile service.

During early 1967, tests in which VHF communications were relayed via satellite (ATS-1) between a U. S. Coast Guard ship and U. S. ground terminals were conducted. These tests, primarily of an operational nature, used equipment aboard the ship which was previously used aboard an aircraft for similar tests in the Pacific. The success of these tests provided motivation for a proposal to the ITU World Administrative Radio Conference (WARC).

At the WARC of the International Telecommunication Union, held in Geneva September-November, 1967, the United States presented proposals for the use of space techniques for the maritime mobile service. The conference adopted Recommendation No. GG, developed from the U. S. proposal. The recommendation is to encourage the study by administrations, IMCO and the CCIR, of early development of a system to improve communication and to enhance the safety of life and property at sea, using space communications techniques.

UNITED STATES
INFORMATION AGENCY

CHAPTER XIII

INTRODUCTION

It is USIA, through wireless news, movies, television, photos, exhibits, and other media, that carries the U. S. space story to the world. Working through 225 posts in 104 countries, the staff of the U. S. Information Service reported space operations, events and achievements via these media throughout the year.

Space was the outstanding feature of the U. S. exhibit at Expo 67 at Montreal, prepared by USIA, and visited by 9 million people. Over 500,000 people observed the U. S. spacecraft displayed at the Paris Air Show, world showcase of aerospace. The same number came to see the GEMINI 10 spacecraft during its three-city tour of Japan, while another half-million visited the spacecraft in 25 Australian cities.

Manned space was the key to such interest, and while the U. S. flew no manned flights, man in space was still big news. The successful test of the SATURN V lunar rocket and the APOLLO heat shield at re-entry speed on the APOLLO 4 mission projected as the outstanding achievement of the year. The APOLLO accident, the investigating board's report and the changes made in the spacecraft all received major attention. So did the Soviet space accident. But the Agency gave equal attention to the activation of the space treaty, the SURVEYOR and ORBITER missions, and to BIOSAT-1 and the APPLICATIONS TECHNOLOGY SATELLITES.

GUIDELINES

In treating space news, posts and Agency media sought:

a. To utilize U. S. space achievements so as to underscore world scientific leadership and American strength.

b. To make clear that the U. S. seeks not just to land a man on the Moon, but to develop all phases of space technology--space science, manned and instrumented exploration, and space applications--to produce benefits for man.

c. To establish that the U. S. is dedicated to peace in space through measures for the rule of law and arms control in space, and through cooperating with other nations in developing space for peaceful uses.

d. To establish that the U. S. is committed to cooperate with other nations to develop space for peaceful uses--by conducting joint space investigations and experiments, by joint activities for obtaining global measurements from space, and by providing experience for foreign scientists and agencies in space science and technology.

e. To demonstrate that the U. S. conducts its civilian manned space operations openly and makes space findings available to all.

f. To make clear that space failures can and will occur in a program that is experimental in nature and unprecedented in scope, and challenges the unknown.

g. To establish that the U. S. still hopes to land astronauts on the Moon by the end of the decade despite the delays resulting from the January, 1967, APOLLO mishap at Cape Kennedy--delays during which the spacecraft has been redesigned and new inspection procedures installed. As always, safety will take precedence over schedule in setting future flight dates.

h. To demonstrate the range and innovations of U. S. space technology, and its value in the everyday lives of men.

i. To show that space technology is being developed to put space to work for man - through extending scientific knowledge, advancing the industrial arts, and building useful and practical applications.

j. To portray the NASA civilian-directed program as non-military in nature, developing space for peaceful purposes. At the same time Department of Defense military-directed space activities--communications and navigation satellites, MANNED ORBITING LABORATORY and missile systems--are described as peaceful programs in that they strengthen the free world and afford it peaceful options.

LEADERSHIP IN SPACE

Both the U. S. and the Soviet Union suffered a space disaster and registered major achievements. While the Cape Kennedy fire set the U. S. manned program back by over a year, it did not produce a psychological disaster abroad. The dead astronauts were mourned by the world as a universal loss, and despite the investigating board's frankness in fixing the blame, the U. S. space image was only temporarily damaged.

The Soviet's VENUS 4 reduced the achievement of MARINER 5 in the public eye, and the automatic docking of two Soviet spacecraft reaffirmed that the Soviet program was still ambitious and active. The successful APOLLO 4 mission that followed, however, more than countered previous psychological gains by the Russians. Discussing the audacity of holding the first SATURN V test in public, the Sunday Telegraph of London remarked, "When the Russians get to that stage with their own hitherto secretive program, they can begin to talk about triumphs on Earth as well as in outer space."

TREATMENT

APOLLO Program

Agency media covered the APOLLO 4 mission as a major event. The Voice of America covered the launch live in World-Wide English, while all other language desks carried news, analyses, comment and reports from launch to recovery. Posts were prepared to capitalize on the event by an APOLLO lecture kit with slides, among other materials.

Other aspects of manned space received extended attention from the Voice, which did 17 individual broadcasts of "U. S. Moon Program Begins," 42 of "GEMINI 9," 18 of "Newest Astronauts," 3 of "How to Feed an Astronaut," 17 of "A Hospital in Space," and 19 of "After APOLLO - What?" There were 62 individual broadcasts on the APOLLO accident, 39 on the astronaut funerals, 11 clarifying the causes of their death, 12 on changes made in the spacecraft, and 9 of a discussion by the astronauts of the spacecraft and its future.

The Agency's wireless service sent to newspapers and U. S. missions abroad 21 stories, totaling 10,250 words, on the APOLLO program. For background coverage a series of five articles, "The Current Status of America's Manned Space Flight Program," was prepared. A paper show on Expo 67, showing four pictures of the U. S. space exhibit, was distributed in 3,289 copies.

An Agency film production, "Behind the Spaceman," had one of the largest print orders ever for USIS: 641. Shown around the clock at the Paris Air Show, the film tells the story of the ordinary men and women whose combined efforts make U. S. manned space possible. One post described it as "an excellent film that tells more about the space program than most of the previous documentaries on launchings put together." The film has been distributed in 28 languages.

SURVEYORS and ORBITERS

SURVEYORS 3, 5, and 6, and LUNAR ORBITERS 3, 4, and 5 were presented as outstanding, successful space technology projects, having virtually completed their principal assignment of scouting astronaut landing sites. Photos from both series were widely serviced, posts getting 2,457 prints and 2,665 plastic plates of SURVEYOR pictures, while the wire service carried 22 stories on the Moon landers. ORBITER pictures went out in the amount of 4,437 prints, plus 5,330 plastic plates.

MARINER 5

This remarkable probe of the environment of Venus, which occurred almost simultaneously with the soft landing of the Soviet VENERA 4 on the planet, was treated as of equal scientific importance--if somewhat less spectacular. It was pointed out that results from the two missions were basically complementary, and that the seeming contradictions would ultimately be worked out by scientists from both nations. Also, while the Soviet soft landing was a considerable feat, previous U. S. accomplishments in interplanetary exploration were equally impressive in their way, and the only such successes until VENERA 4.

Space Treaty

The outer space treaty received extensive treatment when, on October 10, it became effective. Agency media pointed out that the treaty was a response to an initiative by President Johnson; a major measure towards keeping the peace; and the beginning, not the end, of a process of meaningful cooperation with the Soviets on space matters. The President's remark that the first space decade had witnessed a kind of contest, while the next one "should increasingly become a partnership," was the keynote for future media comment in this area.

Press and Publications

U. S. space activities are an integral component of the Agency's Press Service output. The wireless file through the year carried 190 stories on space, totaling 80,000 words. On space findings and international space cooperation, for example, there were 27 stories.

Fast news pictures airmailed to posts by pouch included, besides APOLLO/SATURN, SURVEYORS, and LUNAR ORBITERS, INTELSAT, ESRO, OSO, OGO, BIOSAT, MOL, and the U. S. space exhibit at Expo, with the latter group totaling 21 newspictures, two transparencies, and three plastics. (Each black and white picture serviced by the Agency goes to 149 posts in 189 prints and 95 copy negatives, each color transparency to 50 posts in 74 duplicates, and each plate to 87 posts in 2,665 plastic plates.)

U. S. space was surveyed in a ten-part feature packet, "American in Space: the First Ten Years." Other background coverage included 18 items in "Monthly Science Notes", seven "Science Today" columns, eight special articles, and 12 byliners by leaders in the space field.

"America Illustrated" carried to Russian and Polish readers in its October issue a painting of Astronaut Gordon Cooper on the cover and articles on Cape Kennedy, Dr. Robert Goddard, APOLLO, GEMINI, space benefits, and application satellites. "Topic" told African readers about Project APOLLO and the Houston Manned Spacecraft Center, and carried two features of pictures taken from space.

In the pamphlets area, "Destination: The Moon" was updated through the GEMINI program, while a pamphlet by Leonard Marks, Director of USIA, entitled "Communications Satellites: What Role in Education?", was printed in English, Spanish, French, and Portuguese--132,322 copies in all. A four-page leaflet on U. S. weather satellites, and another on the U. S. role in space will be distributed early in 1968.

Radio

Space is regularly covered in daily news bulletins by all elements of the Voice of America. In addition, the News and Current Affairs Division, central source of scripts on space that are used by World-Wide English Division and translated and broadcast by the 36 foreign language services of the Voice, issued 107 such scripts. The language services turned out 982 more for a grand VOA total of 1,089 scripts on space.

These individual scripts, however, can be and are used many times. Thus News and Current Affairs' 107 scripts on space resulted in 1,335 individual broadcasts, while the language elements' 982 additional scripts produced 2,423 additional broadcasts on space - or a Voice total of 3,758 for the year.

These programs ranged from full treatment of APOLLO and the lunar exploration programs to a report on "Peru Joins Space Consortium" (four individual broadcasts).

Motion Pictures and Television

USIA film productions in space included "The New Explorers," a report on the goodwill tour of Latin America by Astronauts Armstrong and Gordon, of which over 164 prints were distributed to USIS in 19 countries. The Agency also contributed special reports to the Japanese MBS Discussion Series (space spin-off benefits, and research at NASA's Langley Center), KRO/TV of Holland (APOLLO inquiry, and new developments in space), and other television systems.

"Science Report," a bi-monthly television report on U. S. science, distributed in English, French, Spanish, Portuguese, and a music-and-effects track (for language insertion) in 77 countries, carried a review on the GEMINI program, a space review of 1966, and reports on SURVEYOR 3 and space benefits. Clips on Intelsat, the SATURN roll-out, and the space treaty were prepared in 10 languages for telecast abroad. At least 30 other film clips for local newsreel or television use covered the funeral of the astronauts, BIOSAT, SATURN 5, testing of a one-man flying device, and other topics.

A 30-minute color film on APOLLO, for release next year, is in production. So is "Space Benefits," an animated short.

Exhibits

Space exhibits, from the Paris Air Show and the GEMINI 10 tour of Japan and Australia, to such small multi-copy exhibits as "U. S. Progress in Space" drew "clocked" audiences of 2,254,300 in 17 countries on all the continents. Viewers included chiefs of state, village chiefs, and many other opinion moulders.

In addition, 90 space exhibits on constant tour among over 300 USIA outlets attracted between four and five millions. These exhibits included full-scale or lesser-size models of GEMINI, SYNCOM, and MERCURY, as well as the small models used by lecturer-drivers of the touring Spacemobiles. In Portugal, the U. S. Ambassador called the "U. S. Space Exploration Program" "the most effective public event sponsored by USIS in Portugal in the past year."

Information Centers

Through its Information Centers, USIA made a variety of materials on space available. Over two dozen books on space published in the U. S. were recommended to Posts for acquisition. For Norway's top television commentator, a set of 64 slides on the U. S. space program was made available, and used later for a USIS-sponsored lecture tour of northern Norway. Fully 24 books on space were published, in USIS-sponsored series, in 19 languages; a total of a quarter-million copies of these volumes were distributed. Harold L. Goodwin's "All About Rockets and Space Flight," for example, was published in Chinese, Punjabi, Telegu, and Urdu, for a total of 21,000 copies. The Agency also distributed for presentation to libraries 300 copies of "Earth Photographs from GEMINI 3, 4, 5," published by NASA, and, for presentation to universities, 300 copies of "United States Activities in Spacecraft Oceanography," a booklet prepared by NASA and the Navy Oceanographic Office on how satellites and manned spacecraft can forward oceanographic investigation.

ARMS CONTROL AND DISARMAMENT AGENCY

CHAPTER XIV

INTRODUCTION

The Arms Control and Disarmament Agency's interest in space is reflected in international negotiations and in its research programs. ACDA regards the Outer Space Treaty, which prohibits the placing of nuclear weapons or other kinds of weapons of mass destruction in outer space as well as the establishment of military installations on the Moon and other celestial bodies, as a major milestone in precluding the expansion of the arms race to outer space. Space, rather than becoming a new arena for arms deployment, should be a medium for promotion of understanding and cooperation between nations.

Space programs can serve to enhance national images and divert resources of material and technical manpower to peaceful competition. Outer space cooperative programs encourage the growth of international institutions that will be useful in implementation of future arms control agreements, particularly with respect to verification procedures. Part of ACDA's research seeks to determine the best organization and techniques for monitoring such agreements, and space technology and organizations offer many opportunities for the development of effective arrangements.

ARMS CONTROL PROGRAMS

Preventing the Extension of the Arms Race to Space

The Outer Space Treaty had its genesis in the 1963 U.N. resolution that expressed the intention of all parties to refrain from stationing weapons of mass destruction in outer space. This agreement, the most important arms control development since the Limited Test Ban Treaty of 1963, prohibits the installation of military bases, installations, and fortifications, the testing of weapons, and the conduct of maneuvers on the Moon and other celestial bodies. It provides inspection rights to check compliance with the treaty.

Of more immediate importance, the Outer Space Treaty prohibits placing in orbit around the Earth, stationing on celestial bodies, or otherwise stationing in outer space weapons of mass destruction. At the ceremony marking the signing of the Protocol of Deposit of the Treaty, the President stated, "By adding this treaty to the law of nations, we are forging a permanent disarmament agreement for outer space. The spirit of international cooperation that has achieved this agreement is a beacon of hope for the future."

ACDA's research program--both internal and contract--provided useful support during negotiations of this treaty and continues to support studies directed toward further exploitation of space to promote U.S. arms control and disarmament goals.

Space Cooperation as an Aid to Arms Control

There continues to be a close relationship between our space program and our arms control objectives. As additional countries become engaged in space activity, greater awareness of a common interest is developing, thus enhancing the atmosphere of mutual trust. Cooperation in all areas of the peaceful uses of outer space helps to foster an atmosphere of mutual understanding in which negotiations of arms control agreements become more probable.

ACDA has actively supported peaceful space cooperative programs, both those in which the U. S. is involved and those involving other nations, such as the European Launcher Development Organization (ELDO). Programs of the type ELDO is developing can help to restrain the proliferation of rocket technology applicable to ballistic missiles. ACDA has also supported negotiations for furtherance of the rule of law in outer space conducted in the Legal Subcommittee of the U. N. Committee on the Peaceful Uses of Outer Space. The cooperative experience gained in the return of astronauts or space objects, as well as the orderly payment of liability resulting from a space activity, will enhance the prospects for orderly administration of future arms control agreements.

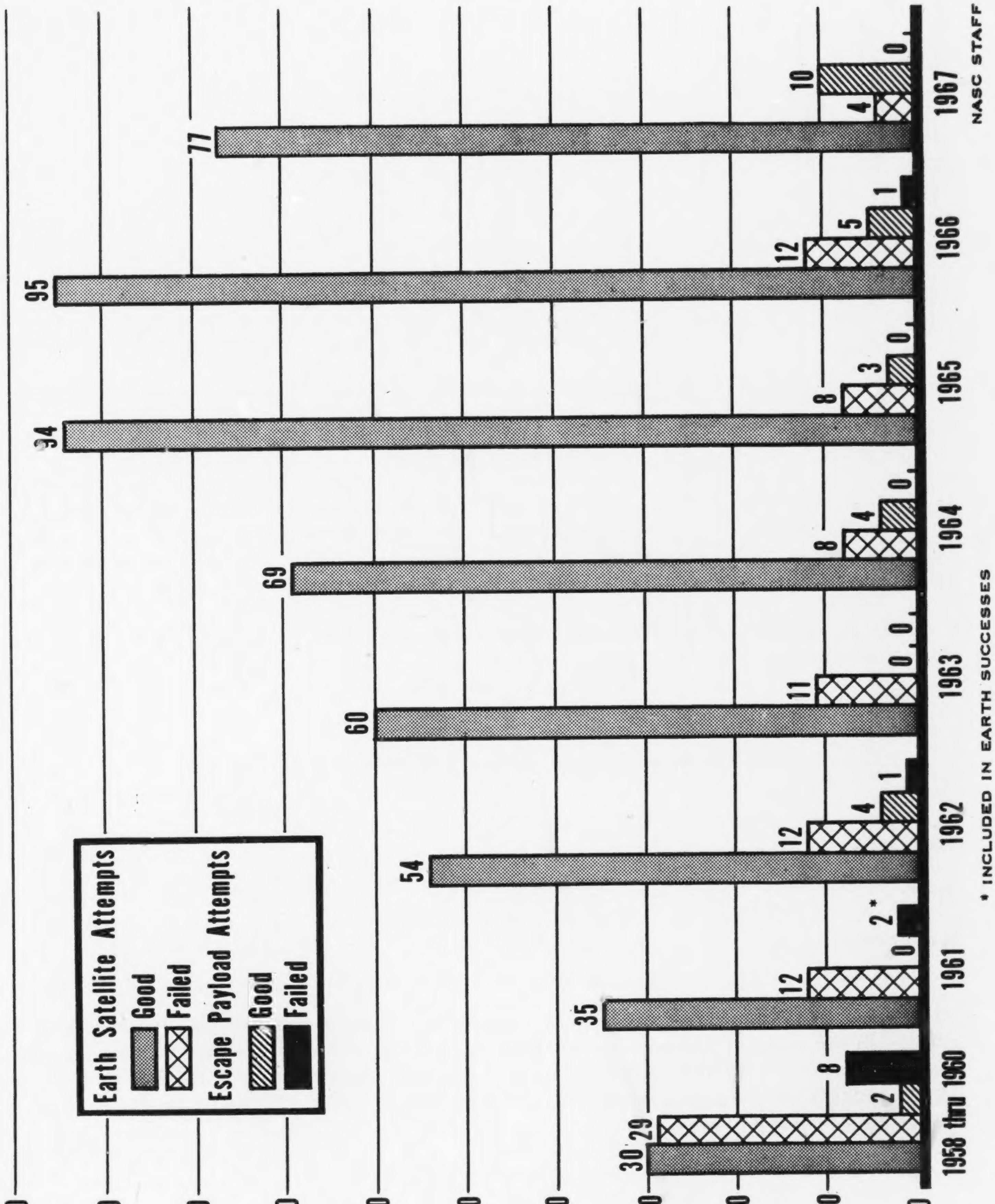
Use of Space Vehicles for Inspection and Verification

The universally recognized benefits of weather satellites, the multi-national development of a global communications system, and the growing worldwide interest in Earth resources satellites provide both technical foundation and important precedent for the verification of possible future arms control agreements by observation satellites. ACDA's research continues to study the opportunities that space technology offers for achieving arms control objectives in this verification area. Particular attention has been given to remote sensors such as cameras, spectrometers, and radiometers which might detect the existence, deployment, characteristics, testing, etc. , of various weapon systems along with advanced techniques for data handling and interpretation.

Interaction of Arms Control Measures with Space Program

ACDA is continuing its studies to establish safeguards and procedures which would insure continuation of peaceful space programs under a strategic defensive and offensive weapon systems freeze. Even though Soviet reaction to date on our various freeze proposals has been negative, the Agency, in cooperation with NASA, has continued its studies of the problem of restraining military missile development programs with adequate verification without restricting peaceful space programs.

U.S. SPACECRAFT RECORD



U. S. SPACECRAFT RECORD

	Earth Orbit		Earth Escape	
Year	Success	Failure	Success	Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	2*
1962	54	12	4	1
1963	60	11	0	0
1964	69	8	4	0
1965	94	8	3	0
1966	95	12	5	1*
1967	77	4	10	0
Total	514	97	28	12

The criterion of success or failure used is the attainment of Earth orbit or Earth escape rather than a judgment of mission success.

This tabulation includes one British, one Canadian, and one French spacecraft launched by the U. S., one Italian spacecraft launched by an Italian crew using a U. S. launch vehicle from U. S. territory, one U. S. launch failure carrying an ESRO spacecraft, and two U. S. spacecraft carrying British experiments.

* These Earth escape failures did attain Earth orbit and therefore are included in the Earth-orbit success totals.

USSR SPACECRAFT SUCCESSFULLY LAUNCHED

Year	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	Total
Spacecraft	2	1	3	3	7	21	18	38	73	51	67	284

USSR tabulation combines successfully launched Earth-orbit and Earth-escape spacecraft. In the total of 284 are included 21 spacecraft launched on Earth-escape missions, 12 spacecraft intended for escape missions but attaining only Earth orbit, and 23 spacecraft used as launching platforms in low parking orbits for higher-orbit missions or Earth escape.

SUCCESSFUL U.S. LAUNCHES - 1967

Launch Date (GMT) Spacecraft Name COSPAR Designation Launch Vehicle	Spacecraft Data	Apogee and Perigee (in statute miles) Period (minutes) Inclination to Equator (degrees) * retrograde incl.	Remarks
Jan. 11 INTELSAT II-B 1A Thor-Delta	Objective: To place spacecraft into an earth synchronous orbit over the Pacific Ocean as part of the INTELSAT Global Communication system. Spacecraft: Cylindrical shape 56" dia. by 26.5"; spin stabilized; 85 watt solar cell power supply; 240 voice channel (equivalent) communication capacity; 15 watts effective radiated power. Weight: 192 lbs.	22,442 22,235 1,436 1.42	INTELSAT II-B started commercial operations over the Pacific on January 26, 1967.
Jan. 14 DEFENSE 2A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	227 123 90 80.08	Decayed February 2, 1967.
Jan. 18 IDCSP 8, 9, 10, 11, 12, 13, 14, and 15 3A, B, C, D, E, F, G, and H Titan IIIC	Objective: Establish an interim defense communication satellite system. Spacecraft: Symmetrical 24 face polyhedron, 36" dia. by 32" high; spin stabilized; 40 watt solar cell power supply; low channel capacity; X-band. Weight: each spacecraft 100 lbs.	(Orbital Range) 20,993 - 21,261 20,836 - 20,927 1,330.0 - 1,343.2 0.08 - 0.18	Spacecraft are operating in a near-synchronous constellation along with seven earlier spacecraft launched on June 16, 1966.
Jan. 26 ESSA IV 6A Thor-Delta	Objective: Operate an Automatic Picture Transmission (APT) system in a sun-synchronous orbit with a local equator crossing time between 9:00 and 9:20 a.m. Spacecraft: Cylindrical 18 sided polygon 42" dia. and 22" high; spin stabilized; solar cell power supply. Weight: 290 lbs.	888 822 113 102*	Spacecraft functioning normally and ESSA reported photos are of excellent quality.
Feb. 2 DEFENSE 7A Atlas-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	396 96 88.8 102.4*	Decayed February 12, 1967.
Feb. 5 LUNAR ORBITER III 8A Atlas-Agena	Objective: Conduct a detailed photographic survey of various lunar surface areas of interest to APOLLO and SURVEYOR as landing sites, and improve our knowledge of the moon. Spacecraft: Conical shaped main body 60" dia. and 66" high and 144" across extended solar cell arms; gas jet 3-axis stabilization; 375 watt solar cell power supply. Weight: 850 lbs.	Initial Lunar Orbit: 1,117 130 215 20.9 Final Lunar Orbit: 1,149 33 209 20.8	Photographed 12 APOLLO landing sites, but a failure in a photo subsystem prevented readout of low resolution photos of the 6 easterly sites; these were, however, covered by high resolution photos. Photographed soft-landed SURVEYOR I. With LUNAR ORBITER II, acted as tracking target to exercise APOLLO network on lunar-distance tracking. Was intentionally crashed onto the moon on October 9, 1967.
Feb. 8 DEFENSE 10A Thor-Burner II	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	543 503 101.4 98.8*	Still in orbit.
Feb. 22 DEFENSE 15A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	228 107 90.1 80.0	Decayed March 11, 1967.
Feb. 24 DEFENSE 16A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	242 96 89.8 106.9*	Decayed March 6, 1967.

Mar. 8 OSO III 20A Thor-Delta	Objective: Continue OSO I and II studies of sun and its effect on earth's upper atmosphere by obtaining high-resolution spectral data from two pointed and environmental data from seven spinning sun experiments during major portion of one solar rotation. Spacecraft: Revolving 9-sided polyhedron, 44" dia. by 15" high, with a sun pointing 22" radius semicircular sail; spin stabilized; 26 watt solar cell power supply. Weight: 627 lbs.	354 336 96 33	All experiments were successful. With the exception of one experiment, which completed its mission during the first six months, the spacecraft is still providing useful data.
Mar. 23 INTELSAT II-C 26A Thor-Delta	Objective: To place spacecraft into an earth synchronous orbit over the Atlantic Ocean as part of the INTELSAT Global Communication system. Spacecraft: Cylindrical shape 56" dia. by 26.5"; spin stabilized; 85 watt solar cell power supply; 240 voice channel (equivalent) communication capacity; 15 watts effective radiated power. Weight: 192 lbs.	22,250 22,221 1,436 .804	INTELSAT II-C started commercial communications operations over the Atlantic on April 6, 1967.
Mar. 30 DEFENSE 29A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	246 114 90.2 85.0	Decayed April 17, 1967.
Apr. 6 ATS II 31A Atlas-Agena D	Objective: From a 6,900 mile orbit obtain gravity stabilization evaluation data and conduct a series of application, technology, and scientific experiments. Spacecraft: Cylinder 56" dia. by 72" high; four movable 127' booms, X-configured, plus 45' damper booms; 185 watt solar cell power supply. Weight: 715 lbs.	6,033 101 219.7 28.3	Agena engine failed to ignite for 2nd burn, did not achieve intended 6,900 mi. circular orbit. This limited the usefulness of gravity-gradient experiment and of most other experiments, although all experiments did return some data. Still transmitting.
Apr. 13 DEFENSE 34A Scout	Objective: To provide a navigation satellite capability. Spacecraft: Not announced.	673 665 106.5 90.2*	Still in orbit.
Apr. 17 SURVEYOR III 35A Atlas-Centaur	Objective: Soft land on moon east of SURVEYOR I landing site within zone of APOLLO interest; obtain post-landing TV pictures of lunar surface; manipulate lunar surface with surface sampler and observe effects with TV camera. Spacecraft: Triangular three-legged frame, 10' high and 14' between legs; solar cell power supply. Landing weight: 625 lbs.	Soft-landed on moon.	SURVEYOR III soft-landed within 1.7 miles of intended target in eastern part of Oceanus Procellarum after bouncing 3 times in landing. SURVEYOR III took 6,315 TV pictures and operated surface sampler, establishing lunar bearing strength of 3 to 8 psi. Also photographed the earth in color and a solar eclipse. Failed to respond to commands after first lunar night.
Apr. 20 ESSA V 36A Thor-Delta	Objective: Operate an Advanced Vidicon Camera System in sun-synchronous orbit with a local equator crossing time between 3:00 p.m. and 3:20 p.m., providing daily pictures of the entire globe. Spacecraft: Cylindrical 18-sided polyhedron 42" dia. by 22" high; spin stabilized; solar cell power supply. Weight: 320 lbs.	881 840 113.5 101.9*	All systems functioned normally; photos of excellent quality.
Apr. 28 Vela Satellite 40A and B Titan IIIC	Objective: Conduct research on nuclear test detection techniques. Spacecraft: Cylindrical 26-sided polyhedron 56" dia. and 46" high. Reaction wheel plus gas jet stabilization; 120 watts solar cell power supply; Weight: 508 lbs.	40A: 69,972 67,799 6,655.1 32.1 40B: 71,216 66,805 6,671.8 33.1	Both still in orbit.

Apr. 28 ERS-18 40C Titan IIIC	Objective: Investigate natural radiation background in space. Spacecraft: Octahedron 11" on a side; spin stabilized, random orientation; 5.5 watt solar cell power supply. Weight: 20 lbs.	69,123 5,338 2,831.3 32.8	Still in orbit.
Apr. 28 ERS-20 40D Titan IIIC	Objective: Correlate differences of friction behavior of material specimens in space and in vacuum chambers. Spacecraft: Octahedron 11" on a side; spin stabilized,random orientation; 5.5 watt solar cell power supply. Weight: 14 lbs.	69,122 5,338 2,831.2 32.8	Still in orbit.
Apr. 28 ERS-27 40E Titan IIIC	Objective: Provide single station readout of X-ray (0.5-14 A^{o}), electron (.04-33 MEV) and proton (1-80 MEV) detectors. Spacecraft: Octahedron 11" on a side; spin stabilized, random orientation; 5.5 watt solar cell power supply. Weight: 20 lbs.	69,122 5,338 2,831.0 32.8	Still in orbit.
May 4 LUNAR ORBITER IV 41A Atlas-Agena D	Objective: Conduct a broad, systematic photographic survey of major portion of lunar surface to provide basis for selecting sites for more detailed study by subsequent orbital and landing missions. Spacecraft: Conical shaped main body 60" dia. and 66" high and 144" across extended solar cell arms; gas jet 3-axis stabilization; 375 watt solar cell power supply. Weight: 850 lbs.	Lunar orbit: 3,797 1,681 721 85.5	LUNAR ORBITER IV went into elliptical lunar orbit, photographed 99% of earth side of moon, raised to 80% the total coverage of the hidden side of the moon by the four Lunar Orbiters. Photo readout was completed June 1. Presumed to have crashed onto the moon during Oct-Nov 1967.
May 5 ARIEL III (UKE-3) 42A Scout	Objective: To extend atmospheric and ionospheric investigations conducted by ARIEL I and II. Spacecraft: Cylindrical 12-sided polygon 23" dia. and 35" high. Spin stabilized; solar cell power supply. Weight: 198 lbs.	373 306 95.6 80	Third U.K. satellite, launched by the U. S. All experiments successful and returned good data. Still in orbit and transmitting.
May 9 DEFENSE 43A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	492 114 94.3 85.0	Decayed July 13, 1967.
May 9 DEFENSE 43B Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	501 346 98.4 84.9	Still in orbit.
May 18 DEFENSE 48A Scout	Objective: To provide a navigation satellite capability. Spacecraft: Not announced.	678 667 106.9 89.5	Still in orbit.
May 22 DEFENSE 50A Atlas-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	151 102 89.3 91.5*	Decayed May 30, 1967.
May 22 DEFENSE 50B Atlas-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	121 99 88.3 91.4*	Decayed May 27, 1967.
May 24 EXPLORER XXXIV 51A Thor-Delta	Objective: To investigate the space region between the magneto-sheath and the shock front and obtain data on the cislunar environment out to distances of 150,000 miles. Spacecraft: Octahedron 28" dia. and 8" high; spin stabilization; 70 watt solar cell power supply; Weight: 163 lbs.	133,131 150 6,360 67.2	Ten of eleven experiments successfully returned data in excess of the mission objective of three months. Still in orbit and transmitting.
May 31 DEFENSE 53 B, C, D, E, F, G, H, and J Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	572-578 568-576 103.5 69.9	Still in orbit.

Jun. 4 DEFENSE 55A Atlas-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	157 148 89.3 104.8*	Decayed June 12, 1967.
Jun. 14 MARINER V 60A Atlas-Agena	Objective: Conduct a 2,000 mile flyby of Venus and obtain scientific information that complements and extends that obtained by MARINER II relating to the origin and nature of Venus and of its environment. Spacecraft: Octahedron 50" dia. and 20" high (with antennae and four solar cell panels overall dimension 18' and 9.5' high); active stabilization; celestial reference; 355 watt solar cell plus battery power supply. Weight: 540 lbs.	.74 au .58 au 194.6 days 1.39	MARINER V flew past Venus at about 2,500-mi. altitude on October 19, 1967. All experiments returned excellent data. Spacecraft is continuing to provide interplanetary environmental measurement data in its heliocentric orbit.
Jun. 16 DEFENSE 62A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	175 105 90.0 80.0	Decayed July 20, 1967.
Jun. 16 DEFENSE 62B Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	329 326 94.9 80.2	Still in orbit.
Jun. 20 DEFENSE 64A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	175 88 89.9 111.5*	Decayed June 30, 1967.
Jun. 29 SECOR (EGRS-9) 65A Thor-Burner II	Objective: To provide an aid to the geodetic survey of the earth sphere. Spacecraft: Not announced.	2,457 2,378 172.1 89.8	Still in orbit.
Jun. 29 AURORA I 65B Thor-Burner II	Objective: To study the charged particles that precipitate in the upper atmosphere to produce auroras. Spacecraft: Rectangular box structure carrying scientific instrumentation; solar cell power supply. Weight: 40 lbs.	2,451 2,366 172.1 89.8	Still in orbit.
Jul. 1 IDCSP 16, 17, and 18 66A, B, and C Titan IIIC	Objective: Establish an interim defense communication satellite system. Spacecraft: Symmetrical 24 face polyhedron, 36" dia. by 32" high; spin stabilized; 40 watt solar cell power supply; low channel capacity; X-band. Weight: each spacecraft 100 lbs.	(Orbital Range) 20,833-20,848 20,497-20,555 1308.8-1311.7 7.1-7.2	Spacecraft are operating as the space segment of the defense communication system in near synchronous orbit constellation along with fourteen of fifteen previously launched IDCSP spacecraft.
Jul. 1 DATS 66D Titan IIIC	Objective: To test and evaluate a mechanically despun antenna system for a spin stabilized spacecraft. Spacecraft: Not announced.	20,857 20,594 1,313.6 7.0	Still in orbit.
Jul. 1 LES-5 66E Titan IIIC	Objective: To provide test data on the feasibility of a tactical communication satellite operating with various types of ground terminals. Spacecraft: Not announced.	20,853 20,609 1,315.4 7.0	Still in orbit.
Jul. 1 DODGE 66F Titan IIIC	Objective: To operate and evaluate a passive 3-axis gravity gradient attitude control experiment at near synchronous altitude. Spacecraft: Truncated octahedron; gravity gradient and flywheel stabilization; solar cell power supply. Weight: 430 lbs.	20,925 20,685 1,319.0 7.0	Still in orbit.
Jul. 14 SURVEYOR IV 68A Atlas-Centaur	Objective: Soft-land on moon in Sinus Medii within zone of APOLLO interest and obtain post-landing TV pictures of the lunar surface. Spacecraft: Triangular three-legged frame, 10' high and 14' between legs; solar cell power supply; landing weight 625 lbs.	Probably crashed.	SURVEYOR IV had excellent launch and flight to moon. At less than 3 min. prior to lunar contact, all communication with spacecraft was suddenly lost. Spacecraft probably crashed. Cause for communications failure could not be determined.

Jul. 19 EXPLORER XXXV 70A Thor-Delta	Objective: To study the solar wind and interplanetary magnetic field at lunar distances, their interaction with the moon, the dust distributions around the moon, the lunar gravitational field and the lunar ionosphere and radiation environment. Spacecraft: Octahedron 28" dia. and 8" high; spin stabilized; sun and earth referenced; 38 watt solar cell power supply. Weight: 230 lbs.	/Lunar orbital data: / 4,780 497 690 147.3*	EXPLORER XXXV was captured in lunar orbit and provided significant scientific data. Still in orbit and transmitting.
Jul. 25 DEFENSE 71A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	378 243 94.5 75.1	Still in orbit.
Jul. 27 OV 1-86 72A Atlas	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	431 346 95.5 101.6*	Still in orbit.
Jul. 27 OV 1-12 72D Atlas	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	431 346 95.5 101.6*	Still in orbit.
Jul. 28 OGO IV 73A Thor-Agena	Objective: To continue the investigation of atmospheric and ionospheric phenomena of the near-earth environment during a period of increasing solar activity, complementing the near solar minimum measurements made by OGO II. Spacecraft: Rectangular box structure 67" by 32" by 31"; active stabilization; 250 watt solar cell plus battery power supply. Weight: 1,240 lbs.	564 256 97.9 86.0	All experiments provided scientific data. Still in orbit and providing data.
Aug. 1 LUNAR ORBITER V 75A Atlas-Agena	Objective: To obtain, from a lunar polar orbit, photography of scientifically interesting sites on the moon, to increase the scientific knowledge of lunar surface features, their nature, origin, and processes, and to serve as a basis for selecting sites for more detailed scientific study by future missions. Spacecraft: Conical shaped main body 60" dia. and 66" high and 144" across extended solar cell arms; gas jet 3-axis stabilization; 375 watt solar cell power supply; Weight: 850 lbs.	/Lunar orbital data during far side photography: / 3,734 121 510 85 /Orbital data for front side photography: / 930 62 192 85	LUNAR ORBITER V photographed 23 previously unphotographed areas on the moon's far side at about 150 meter resolution, the first photo of the "full earth," and 36 sites of scientific interest and 5 APOLLO sites at 2 to 10 meter resolution.
Aug. 7 DEFENSE 76A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	219 117 89.8 79.9	Decayed September 1, 1967.
Aug. 16 DEFENSE 79A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	277 77 90.1 111.5*	Decayed August 28, 1967.
Aug. 23 DEFENSE 80A Thor-Burner II	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	556 517 102.1 98.9*	Still in orbit.
Sep. 7 BIOSATELLITE II 83A Thor-Delta	Objective: To conduct biological experiments on effects of weightlessness and controlled gamma radiation aboard an attitude-controlled orbiting spacecraft for three days and recover. Spacecraft: Cylindrical cone 56" dia. at base 72" high; active stabilization; battery power supply; Weight: 940 lbs.	202 187 90.8 33.5	All BIOSATELLITE II experiments provided useful data. Communications difficulties and prospects of recovery area bad weather led to decision to shorten mission to two days. Spacecraft was recovered by aircraft over Pacific.

Sep. 8 SURVEYOR V 84A Atlas-Centaur	Objective: Soft land on moon in Mare Tranquillitatis; obtain post-landing TV pictures of lunar surface; conduct vernier-engine erosion experiment. Spacecraft: Triangular three-legged frame, 10' high and 14' between legs; solar cell power supply; landing weight 625 lbs.	Soft-landed on moon.	SURVEYOR V landed safely in Mare Tranquillitatis; during its 1st lunar day it took 18,006 pictures, more than SURVEYORs I and III combined. Survived lunar night, took 1,048 photos of poorer quality. Alpha-scattering experiment showed chemistry of soil to be that of basaltic rock; vernier engine firing produced observable but insignificant erosion. Spacecraft was shut down November 1, 1967.
Sep. 15 DEFENSE 87A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	245 94 89.9 80.1	Decayed October 4, 1967.
Sep. 19 DEFENSE 90A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	214 76 89.1 106.0*	Decayed September 30, 1967.
Sep. 25 DEFENSE 92A Scout	Objective: To provide a navigation satellite capability. Spacecraft: Not announced.	693 648 106.7 89.2	Still in orbit.
Sep. 27 INTELSAT II-D 94A Thor-Delta	Objective: To place spacecraft into an earth synchronous orbit over the Pacific Ocean as part of the INTELSAT global communication system. Spacecraft: Cylindrical shape 56" dia. by 26.5"; spin stabilized; 85 watt solar cell power supply; 240 voice channel (equivalent) communication capacity; 15 watts effective radiated power. Weight: 192 lbs.	22,240 22,236 1,436 0.7	INTELSAT II-D started commercial operations over the Pacific on November 4, 1967.
Oct. 11 DEFENSE 96A Thor-Burner II	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	534 418 100.1 99.1*	Still in orbit.
Oct. 18 OSO IV 100A Thor-Delta	Objective: To continue OSO I, II, and III investigations of the sun, to obtain high resolution spectral data (1 to 1,350 Angstrom) from sun-pointed experiments and environmental data from spinning experiments. Spacecraft: Revolving 9-sided polyhedron 44" dia. and 15" high with sun-pointing 22" radius semi-circular sail; spin stabilized; 26 watt solar cell power supply; Weight: 610 lbs.	359 337 95.8 33.0	All experiments functioned normally and provided good data.
Oct. 25 DEFENSE 103A Titan IIIB	Objective: Development of spaceflight techniques and technology Spacecraft: Not announced.	247 78 89.5 111.4*	Decayed November 5, 1967.
Nov. 2 DEFENSE 109A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	255 114 90.4 81.5	Decayed December 2, 1967.
Nov. 2 DEFENSE 109B Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	326 282 94.3 81.6	Still in orbit.
Nov. 5 ATS-III 111A Atlas-Agena D	Objective: To flight test and obtain experimental data from a mechanical despun antenna, a multicolor spin scan cloud camera, a self-contained navigation experiment, an image dissector camera, a resistojet thruster, and several communication experiments. Spacecraft: Cylindrical 58" dia. and 54" long; spin stabilized; 189 watt solar cell power supply; weight 798 lbs.	22,185 21,953 1,422.4 .5	With exception of self-contained navigation experiment, useful data is being obtained from all experiments. Navigation experiment to be exercised early 1968.

Nov. 7 SURVEYOR VI 112A Atlas-Centaur	Objective: Soft land on moon in Sinus Medii; obtain post-landing TV pictures of lunar surface; conduct vernier engine erosion experiment; operate alpha scattering experiment to determine chemical elements of lunar soil. Spacecraft: Triangular three-legged frame, 10' high and 14' between legs; solar cell power supply; landing weight 625 lbs.	Soft-landed on moon.	SURVEYOR VI landed in Sinus Medii and transmitted 30,065 TV pictures during first lunar day; successfully conducted first lift-off from lunar surface and moved 10' to a new location. All experiments highly successful.
Nov. 9 APOLLO 4 113A Saturn V	Objective: To demonstrate the structural and thermal integrity and compatibility of the SATURN V and the APOLLO spacecraft; confirm launch loads and dynamic flight and propulsion system characteristics; and confirm design adequacy of spacecraft design for lunar return velocity re-entry. Spacecraft: In addition to the APOLLO Command Module, the 120' long S-IVB, the Instrument Unit, the APOLLO Adapter, the Service Module, and a boiler place Lunar Module were placed in orbit. The total weight of this orbiting combination was 278,699 lbs.	119 114 88.2 32.6	APOLLO 4 was launched from Launch Complex 39 at ETR, went into earth orbit; after 2 revolutions the S-IVB was fired again, lifting entire combination to peak altitude of 11,240 mi.; S-IVB stage then separated and the Service Module propulsion system accelerated the Command Module to lunar re-entry speed of 36,537 fps. APOLLO Command Module landed 9 mi. from aiming point in the Pacific, was picked up by U.S.S. BENNINGTON. This 1st flight of the SATURN V launch vehicle was a complete success; all stages performed well, the Command Module and its heat shield withstood the temperatures of lunar-speed re-entry.
Nov. 10 ESSA VI 114A Thor-Delta	Objective: To operate an Automatic Picture Transmission (APT) system in a sun synchronous orbit with local equator crossing time between 9:00 and 9:30 a.m. Spacecraft: Cylindrical 18-sided polygon 42" dia. and 22" high; spin stabilized; solar cell power supply. Weight: 290 lbs.	921 872 114.8 102.1*	All systems function normally and ESSA reported excellent photos.
Dec. 5 OV 3-6 120A Scout	Objective: To obtain data on the density, temperature, and composition of the upper atmosphere and its variation with latitude. Spacecraft: Not announced.	275 254 93.0 90.6*	Still in orbit.
Dec. 5 DEFENSE 121A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	266 87 90.1 109.5*	Still in orbit.
Dec. 9 DEFENSE 122A Thor-Agena D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	142 104 88.4 81.6	Still in orbit.
Dec. 13 PIONEER VIII 123A Thor-Delta	Objective: Obtain scientific data on interplanetary phenomena, including magnetic field, plasma, and cosmic rays, in heliocentric orbit for a period covering 2 or more passages of solar activity centers; investigate continuously the magnetosheath at large distances from the bow shock wave. Spacecraft: Cylindrical 37" dia. by 35"; spin stabilized; solar cell plus battery power supply. Weight: 145 lbs.	1.0880au .9892au 386.6 days .057	All experiments are functioning and providing useful data.
Dec. 13 TTS 1 123B Thor-Delta	Objective: To provide a target for Manned Space Flight Network checkout of equipment and training of personnel. Spacecraft: Octahedron 11" on a side; solar cell plus battery power supply. Weight: 40 lbs.	301 182 92.3 32.9	Spacecraft functioning normally.

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL AERONAUTICS AND SPACE COUNCIL
WASHINGTON

December 31, 1967

MAJOR U. S. AND SOVIET "FIRSTS"

One of the indexes used to compare the space programs of the United States and the Soviet Union are the "firsts" achieved by each nation. Since it measures the quantity but not the quality of achievement, such compilation can be misleading. However, when broken down into meaningful areas, it can help in judging emphasis and even relative progress if coupled with other evidence.

Regardless of whether a "first" gives either country a significant lead in a particular area of space technology, the fact of being first is significant in the formation of public opinion. In fact, regardless of actual technological competence, the relative position of the U.S. and the U.S.S.R. in space is often judged by the "firsts" achieved by each.

A list of all of the "firsts" scored by each side would be long and meaningless. An effort has been made to select those actions or accomplishments which seemed to be of major importance, bearing in mind that because of the closed nature of some space activities, the list of major "firsts" may be incomplete.

This list of "firsts" is divided into five broad categories of space interest. This is not a comparison of space competences but rather a cataloging based upon the timing of events.

Appendix B

December 31, 1967

TEN YEAR MAJOR SPACE "FIRSTS"

UNITED STATES		
Event	**Satellite**	**Launch Date**
SCIENCE		
Van Allen radiation belts	Explorer I	2/1/58
Earth shape measured	Vanguard I	3/17/58
Orbiting solar observatory	OSO I	3/7/62
Data from Venus	Mariner II	8/27/62
Geodetic satellite	Anna IB	10/31/62
Lunar close-up pictures	Ranger VII	7/28/64
Mars pictures	Mariner IV	11/28/64
Micrometeorite satellite	Pegasus I	2/16/65
Lunar orbit pictures	Orbiter I	8/10/66
Lunar trenching	Surveyor III	4/17/67
Color picture of full Earth face	Dodge	7/1/67
Lunar soil chemical analysis	Surveyor V	9/8/67
APPLICATIONS		
Active communications	Score	12/18/58
TV pictures from space	Explorer VI	8/7/59
Weather satellite	Tiros I	4/1/60
Navigation satellite	Transit IB	4/13/60
Missile detection	Midas II	5/24/60
Passive communications	Echo I	8/12/60
Nuclear explosion detection	Vela Hotel	10/17/63
BIO AND MANNED FLIGHT		
Manned orbital maneuver	Gemini III	3/23/65
Controlled extravehicular activity	Gemini IV	6/3/65
Space rendezvous	Gemini VI, VII	12/4/65
Manned docking of two craft	Gemini VIII-Agena	3/16/66
SPACE FLIGHT AND PROPULSION		
Multiple payloads and orbits	Transit/Solrad	6/22/60
Payload recovery	Discoverer XIII	8/10/60
Air snatch payload recovery	Discoverer XIV	8/18/60
Synchronous satellite	Syncom II	7/26/63
Hydrogen-fueled rocket orbited	Centaur II	11/27/63
Docked spacecraft maneuver	Gemini X-Agena	7/18/66
Lunar lift-off	Surveyor VI	11/7/67
Lunar-return velocity re-entry	Apollo I	11/9/67
AUXILIARY POWER SYSTEMS		
Solar cells on craft	Vanguard I	3/17/58
Isotope power on craft	Transit IVA	6/29/61
Nuclear energy powered craft	Transit VBNI	9/28/63
Nuclear reactor in orbit	Snapshot I	4/3/65
Fuel cell use in space	Gemini V	8/21/65

UNION OF SOVIET SOCIALIST REPUBLICS		
Event	**Satellite**	**Launch Date**
SCIENCE		
Orbiting geophysical lab	Sputnik III	5/15/58
Farside lunar picture	Luna III	10/4/59
Cosmic ray measurements	Proton I	7/16/65
Lunar surface pictures	Luna IX	1/31/66
Lunar surface bearing test	Luna XIII	12/21/66
Venus atmospheric entry probe	Venera IV	6/12/67
APPLICATIONS		
BIO AND MANNED FLIGHT		
Biosatellite	Sputnik II	11/3/57
Recovery of orbited animals	Sputnik V	8/19/60
Manned flight and recovery	Vostok I	4/12/61
Multi-manned spacecraft	Voskhod I	10/12/64
Extravehicular activity	Voskhod II	3/18/65
SPACE FLIGHT AND PROPULSION		
Space flight	Sputnik I	10/4/57
Earth escape spacecraft	Luna I	1/2/59
Lunar impact	Luna II	9/12/59
Orbital platform launch	Sputnik V	2/12/61
Venus flyby	Venera I	2/12/61
Mars flyby	Mars I	11/1/62
Venus impact	Venera III	11/16/65
Luna soft landing	Luna IX	1/31/66
Luna Orbiter	Luna X	3/31/66
Venus soft landing	Venera IV	6/12/67
AUXILIARY POWER SYSTEMS		
Battery powered spacecraft	Sputnik I	10/4/57

NATIONAL AERONAUTICS AND SPACE COUNCIL STAFF

HISTORICAL SUMMARY - UNMANNED LUNAR AND PLANETARY PROGRAMS

The U.S. unmanned lunar and planetary programs have performed a wide range of missions, with 32 launches in the first decade of U.S. spaceflight. The unmanned lunar program concludes with the launch of Surveyor VII in January, 1968. The planetary program currently has two Mariner flybys of Mars scheduled for launch in the spring of 1969.

Mission and Launch Date	Launch Vehicle and Spacecraft Weight	Highlights
	LUNAR PROGRAM	
Able I Aug. 17, 1958	Thor-Able 84 lb.	First-stage failure.
Pioneer I Oct. 11, 1958	Thor-Able 84 lb.	Probe reached apogee of 70,700 miles. Final stage had premature shutdown.
Pioneer II Nov. 8, 1958	Thor-Able 87 lb.	Third-stage failure.
Pioneer III Dec. 6, 1958	Juno II 13 lb.	Probe reached apogee of 63,580 miles. Final stage had premature shutdown.
Pioneer IV March 3, 1959	Juno II 13 lb.	Passed within 37,300 miles of Moon.
Atlas-Able IV Nov. 26, 1959	Atlas-Able 372 lb.	Launch vehicle shroud failure.
Atlas-Able VA Sept. 25, 1960	Atlas-Able 387 lb.	Second-stage failure.
Atlas-Able VB Dec. 15, 1960	Atlas-Able 388 lb.	First-stage failure.
Ranger III Jan. 26, 1962	Atlas-Agena B 727 lb.	Second-stage failure. Spacecraft passed within 22,862 miles of Moon.
Ranger IV April 23, 1962	Atlas-Agena B 730 lb.	First U. S. lunar impact. Spacecraft failure.
Ranger V Oct. 18, 1962	Atlas-Agena B 755 lb.	Missed Moon by 450 miles. Spacecraft failure.
Ranger VI Jan. 30, 1964	Atlas-Agena B 804 lb.	Impacted Moon. TV system failure.
Ranger VII July 30, 1964	Atlas-Agena D 806 lb.	Impacted Moon. First U. S. lunar success. Returned 4,308 photos.
Ranger VIII Feb. 17, 1965	Atlas-Agena B 809 lb.	Impacted Moon. Returned 7,137 lunar photos.
Ranger IX March 21, 1965	Atlas-Agena B 809 lb.	Impacted Moon. Returned 5,814 photos.

Surveyor I May 30, 1966	Atlas-Centaur 2,193 lb.	First U. S. soft landing. Returned over 11,150 photos.
Surveyor II Sept. 20, 1966	Atlas-Centaur 2,204 lb.	Crashed on Moon southeast of Copernicus crater. Spacecraft failure.
Surveyor III April 17, 1967	Atlas-Centaur 2,280 lb.	Soft landing. Performed soil sampling and returned over 6,300 photos.
Surveyor IV July 14, 1967	Atlas-Centaur 2,294 lb.	Crashed on Moon in Sinus Medii crater. Spacecraft failure.
Surveyor V Sept. 8, 1967	Atlas-Centaur 2,216 lb.	Soft landing. Made surface chemical analysis and over 19,000 photos.
Surveyor VI Nov. 7, 1967	Atlas-Centaur 2,219 lb.	Soft landing. Made surface chemical analysis and over 30,000 photos; lifted off and returned to lunar surface.
Surveyor VII Jan. 7, 1968	Atlas-Centaur 2,289 lb.	Soft landing. Soil sampling; chemical analysis; over 10,000 photos (1/15/68)
Orbiter I Aug. 10, 1966	Atlas-Agena D 853 lb.	First U. S. orbiting success; 206 wide-angle, 11 high-resolution photos.
Orbiter II Nov. 6, 1966	Atlas-Agena D 861 lb.	Returned 206 wide-angle and 205 high-resolution photos.
Orbiter III Feb. 5, 1967	Atlas-Agena D 850 lb.	Returned 153 wide-angle and 144 high-resolution photos.
Orbiter IV May 4, 1967	Atlas-Agena D 860 lb.	Returned 125 wide-angle and 145 high-resolution photos.
Orbiter V Aug. 2, 1967	Atlas-Agena D 862 lb.	Returned 212 wide-angle and 212 high-resolution photos.

PLANETARY PROGRAM

Mariner I July 22, 1962	Atlas-Agena B 446 lb.	Venus probe; launch vehicle failure.
Mariner II Aug. 26, 1962	Atlas-Agena B 447 lb.	First successful flyby of Venus on Dec. 14, 1962 within 21,600 miles of surface; temperature, and magnetic field and charged particle measurements.
Mariner III Nov. 5, 1964	Atlas-Agena D 575 lb.	Mars probe. Launch vehicle shroud failure.
Mariner IV Nov. 28, 1964	Atlas-Agena D 575 lb.	Passed 6,120 miles from Mars on July 14, 1965; measured atmospheric density; returned 21 photos.
Mariner V June 14, 1967	Atlas-Agena D 540 lb.	Passed within 2,600 miles of Venus on Oct. 19, 1967; measured magnetic field and atmospheric properties.

UNITED STATES SPACE LAUNCH VEHICLES

Vehicle	Stages	Propellant	Thrust (in Thousands of pounds)	Max. Dia. (feet)	Height less Spacecraft (feet)	Payload (pounds)		
						300 NM orbit	Escape	First Launch
Scout	1. Algol (IIB)	Solid	100.9	3.3	64.4	320	50	1965 (60)*
	2. Castor II	Solid	60.7					
	3. Antares II	Solid	20.9					
	4. Altair III	Solid	5.9					
Thor-Delta	1. Thor (DSV-3E-1)	LOX/RP	172	8	81	950	150	1966 (60)
	2. Delta (DSV-3)	IRFNA/UDMH	7.5					
	3. FW-4D	Solid	5.9					
Thrust-augmented Thor-Delta	1. Thor (DSV-3E-1) plus	LOX/RP	170 plus	11	90	1,300	250	1965 (60)
	three TX33-52	Solid	54 each					
	2. Delta (DSV-3)	IRFNA/UDMH	7.8					
	3. FW-4D	Solid	5.9					
Thor-Agena	1. Thor (DM-21)	LOX/RP	170	8	76	1,600	--	1962 (59)
	2. Agena	IRFNA/UDMH	16					
Thrust-augmented Thor-Agena	1. Thor (DM-21) plus	LOX/RP	170	11	76	2,200	--	1963 (60)
	three TX 33-52	Solid	54 each					
	2. Agena	IRFNA/UDMH	16					
Atlas-Agena	1. Atlas booster and sustainer	LOX/RP	388	10	91	6,300	1,150	1961 (60)
	2. Agena	IRFNA/UDMH	16					
Titan II (GLV)	1. Two LR-87	N_2O_4/Aerozine	430	10	90	8,000 @ 105 NM	--	1964
	2. LR-91	N_2O_4/Aerozine	100					
Titan IIIA	1. Two LR-87	N_2O_4/Aerozine	430	10	110	5,000	--	1964
	2. LR-91	N_2O_4/Aerozine	100					
	3. Transtage	N_2O_4/Aerozine	16					
Titan IIIB-Agena	1. Two LR-87	N_2O_4/Aerozine	430	10	112	7,700	1,700	1966
	2. LR-91	N_2O_4/Aerozine	100					
	3. Agena	WFNA/UDMH	16					
Titan IIIC	1. Two 5-segment 120" diameter	Solid	2,400	10 x 30	110	23,000	5,000	1965
	2. Two LR-87	N_2O_4/Aerozine	430					
	3. LR-91	N_2O_4/Aerozine	100					
	4. Transtage	N_2O_4/Aerozine	16					
Atlas-Centaur	1. Atlas booster and sustainer	LOX/RP	388	10	112	9,900	2,700	1962
	2. Centaur (Two RL-10)	LOX/LH	30					
Uprated Saturn I	1. S-IB (Eight H-1)	LOX/RP	1,600	21.6	142	40,000 @ 105 NM	--	1966
	2. S-IVB (One J-2)	LOX/LH	200					
Saturn V	1. S-IC (Five F-1)	LOX/RP	7,570	33	281	285,000 @ 105 NM	98,000	1967
	2. S-II (Five J-2)	LOX/LH	1,125					
	3. S-IVB (One J-2)	LOX/LH	225					

NOTES: Definitive data are difficult to compile. Payload capacity data vary according to the place and direction of launch as well as intended orbital altitude. Vehicles still under development may fall short of or exceed their projected capacities, both in payload and in engine thrust. First stage thrust shown is sea level value. Modifications of existing vehicles have already raised their performance, and future modifications may be expected in several cases. In general, these data apply to the latest versions now under development.

* The date of first launch applies to this latest modification with a date in parentheses for the earlier version.

Propellant abbreviations used are as follows: Liquid Oxygen and a modified Kerosene--LOX/RP; Solid propellant combining in a single mixture both fuel and oxidizer--Solid; Inhibited Red Fuming Nitric Acid and Unsymmetrical Dimethylhydrazine--IRFNA/UDMH; Nitrogen Tetroxide and Aerozine--N_2O_4/Aerozine; Liquid Oxygen and Liquid Hydrogen--LOX/LH.

Values marked -- are either zero or not pertinent for the vehicle.

RADIOISOTOPIC POWER SYSTEMS FOR SPACE APPLICATIONS

Designation	Power Electrical (watts)	Design Life	Application	Fuel	Status
SNAP-3	2.7	5 years	Navigational satellites (DOD)	Plutonium-238	Units launched in June and November, 1961. June unit still operating in orbit, but quantitative performance data not available.
SNAP-9A	25	5 years	Navigational satellites (DOD)	Plutonium-238	Units launched in September and December, 1963, are still operating, but at a lower power level. Third satellite failed to orbit in April, 1964.
SNAP-11	25	90 days	Moon Probe (NASA)	Curium-242	First fueling of a generator with Curium-242 accomplished in July, 1966. In October fueled unit completed 90-day test under simulated conditions. Generator not used since no 90-day lunar missions approved.
SNAP-19	30	1 year	NIMBUS B Weather satellite (NASA)	Plutonium-238	Electrically heated system undergoing compatibility testing with NIMBUS B spacecraft. Two prototype fueled generators tested to flight-system qualification levels.
"Lightweight" Generators	30	more than 2 years	Navigational satellite	Plutonium-238	Demonstration generators going into electrically heated testing in June, 1968
SNAP-27	50	1 year	Apollo Lunar Surface Experiment (ALSEP) (NASA)	Plutonium-238	Electrically heated engineering generators placed on test. Electrically heated prototype system undergoing compatibility testing with ALSEP hardware.
SNAP-29	500	90-120 days	Manned and Unmanned space applications (DOD and NASA)	Polonium-210	Detailed design and subcomponents development initiated. Fueled system scheduled for ground test in 1969.
Isotope-Brayton System	5,500	5 years with replacement components	Manned stations, lunar base (DOD and NASA)	Plutonium-238	AEC will develop isotope source for joint AEC-NASA system ground test in early 1970's.

SPACE ACTIVITIES OF THE UNITED STATES GOVERNMENT

Historical Summary and 1969 Budget Recommendations January 29, 1968

NEW OBLIGATIONAL AUTHORITY

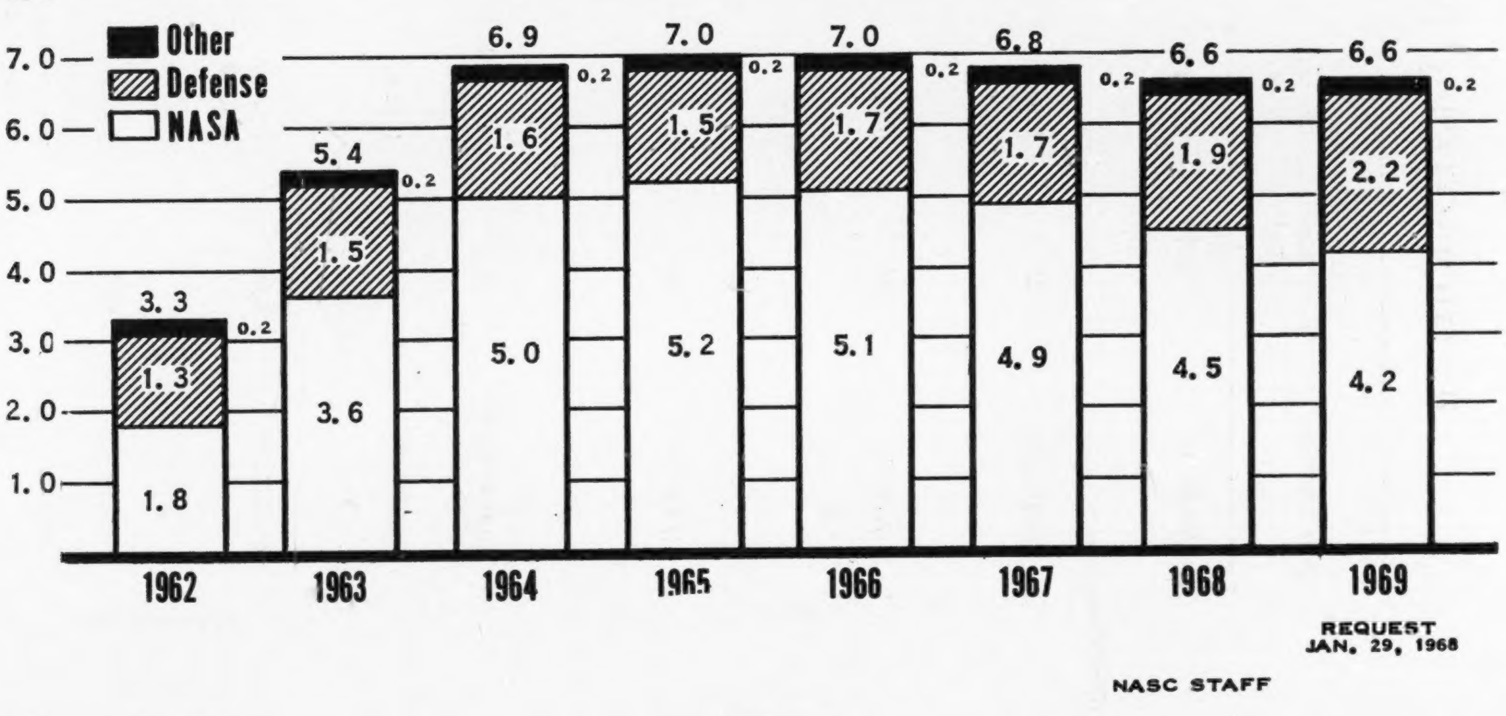
(In millions of dollars)

	NASA		Dept. of		Com-	Inte-	Agri-		Total
	Total	Space 1/	Defense	AEC	merce	rior	culture	NSF	Space
1955	56.9	56.9	3.0	--	--	--	--	--	59.9
1956	72.7	72.7	30.3	7.0	--	--	--	7.3	117.3
1957	78.2	78.2	71.0	21.3	--	--	--	8.4	178.9
1958	117.3	117.3	205.6	21.3	--	--	--	3.3	347.5
1959	305.4	235.4	489.5	34.3	--	--	--	--	759.2
1960	523.6	461.5	560.9	43.3	--	--	--	.1	1065.8
1961	964.0	926.0	813.9	67.7	--	--	--	.6	1808.2
1962	1824.9	1796.8	1298.2	147.8	50.7	--	--	1.3	3294.8
1963	3673.0	3626.0	1549.9	213.9	43.2	--	--	1.5	5434.5
1964	5099.7	5046.3	1599.3	210.0	2.8	--	--	3.0	6861.4
1965	5249.7	5167.6	1579.4	228.6	12.2	--	--	3.2	6991.0
1966	5174.9	5094.5	1692.8	186.8	26.5	4.1	--	3.2	7007.9
1967	4967.6	4862.2	1664.0	183.6	29.3	3.0	--	2.8	6744.9
1969 Budget									
1968	4588.8	4466.1	1949.5	149.7	30.8	2.1	0.4	2.4	6601.0
1969	4370.4	4239.0	2215.9	153.9	30.3	4.0	0.6	2.4	6646.1

1/ Excludes amounts for aircraft technology in 1959 and succeeding years. Amounts for NASA-NACA aircraft and space activities not separately identifiable prior to 1959.

Source: Bureau of the Budget

U.S. SPACE BUDGET - NEW OBLIGATIONAL AUTHORITY



NASC STAFF

SPACE ACTIVITIES OF THE UNITED STATES GOVERNMENT
Historical Summary and 1969 Budget Recommendations January 29, 1968

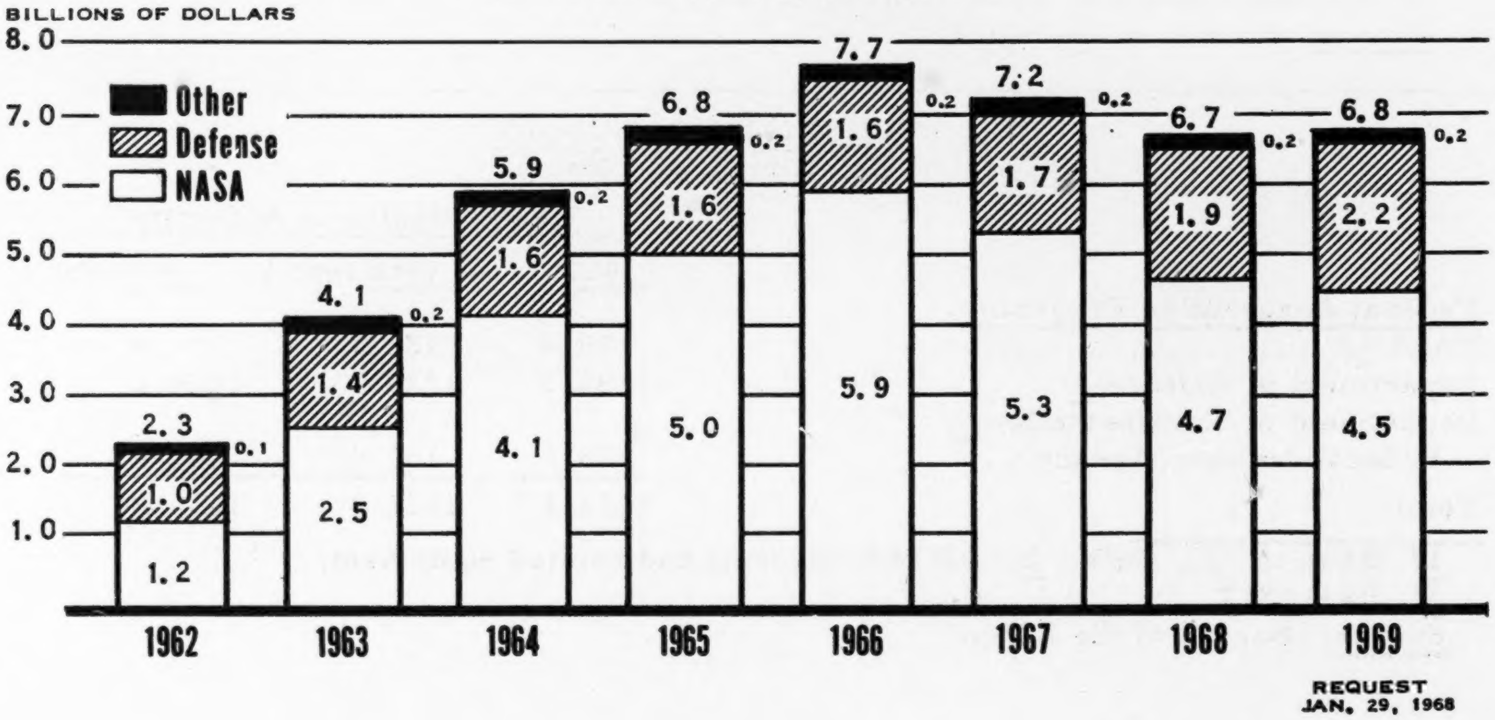
EXPENDITURES
(In millions of dollars)

	NASA		Dept. of		Com-	Inte-	Agri-		Total
	Total	Space 1/	Defense	AEC	merce	rior	culture	NSF	Space
1955	73.8	73.8	1.5	--	--	--	--	--	75.3
1956	71.1	71.1	16.5	6.3	--	--	--	6.2	100.1
1957	76.1	76.1	47.5	19.2	--	--	--	7.3	150.1
1958	89.2	89.2	135.5	20.2	--	--	--	4.0	248.9
1959	145.6	58.8	341.0	32.6	--	--	--	1.5	433.9
1960	401.0	329.2	518.1	41.1	--	--	--	--	888.4
1961	744.3	693.6	710.0	64.3	--	--	--	--	1467.9
1962	1257.0	1225.9	1028.8	130.0	1.0	--	--	.9	2386.6
1963	2552.3	2516.8	1367.5	181.0	12.2	--	--	1.1	4078.6
1964	4171.0	4131.3	1563.5	220.1	12.3	--	--	2.6	5929.8
1965	5092.9	5035.0	1591.8	232.2	24.1	--	--	3.0	6886.1
1966	5933.0	5857.9	1637.4	188.3	28.1	4.0	--	2.8	7718.5
1967	5425.7	5336.7	1673.1	183.6	38.6	2.9	--	2.4	7237.3
1969 Budget									
1968	4805.0	4692.0	1870.0	150.8	32.6	2.0	0.4	2.0	6749.8
1969	4575.0	4455.0	2180.0	150.7	33.8	3.8	0.6	2.0	6825.9

1/ Excludes amounts for aircraft technology in 1959 and succeeding years. Amounts for NASA-NACA aircraft and space activities not separately identifiable prior to 1959.

Source: Bureau of the Budget

U.S. SPACE BUDGET · EXPENDITURES



REQUEST
JAN. 29, 1968

NASC STAFF

SPACE ACTIVITIES BUDGET

1969 Budget Document
January 29, 1968
(In millions of dollars)

	New Obligational Authority			Expenditures		
	1967 (Actual)	1968 (Estimated)	1969	1967 (Actual)	1968 (Estimated)	1969
Federal Space Programs						
NASA 1/	4862.2	4466.1	4239.0	5336.7	4692.0	4455.0
Department of Defense	1664.0	1949.5	2215.9	1673.1	1870.0	2180.0
Atomic Energy Commission	183.6	149.7	153.9	183.5	150.8	150.7
Department of Commerce	29.3	30.8	30.3	38.6	32.6	33.8
Department of Interior	3.0	2.1	4.0	2.9	2.0	3.8
Department of Agriculture	-	0.4	0.6	-	0.4	0.6
National Science Foundation	2.8	2.4	2.4	2.4	2.0	2.0
TOTAL	6744.9	6601.0	6646.1	7237.2	6749.8	6825.9
NASA						
Manned space flight	3393.5	3158.6	2824.8	3648.7	3166.0	2993.3
Scientific investigations	564.4	508.7	479.5	673.7	562.5	497.6
Space applications	110.2	134.3	147.7	127.8	135.4	146.6
Space technology	387.8	398.9	410.1	440.4	420.2	425.3
Aircraft technology	105.4	122.7	131.4	88.6	112.5	119.8
Supporting operations	346.8	325.6	376.8	452.3	408.4	392.4
Adjustments to NOA basis	+59.5	-60.0	-	-	-	-
Total	4967.6	4588.8	4370.4	5425.7	4805.0	4575.0

1/ Excludes amounts for aircraft technology.
Source: Bureau of the Budget

AERONAUTICS BUDGET

(In millions of dollars)

	New Obligational Authority		
	1967	1968 (est.)	1969 (est.)
Federal Aeronautics Programs			
NASA 1/	105.4	122.7	131.4
Department of Defense 2/	1199.2	1230.2	1024.2
Department of Transportation 3/ Federal Aviation Agency	308.5	169.4	251.0
Total	1613.1	1522.3	1406.6

1/ R&D, A.O., CofF; 2/ RDT&E Aircraft and related equipment;
3/ R&D, SST.
Source: Bureau of the Budget

INDEX

A-7 series aircraft 51
Ablation measuring 33
Advanced re-entry tests 55
AEROBEE 31
Aeronautics 8; development activity 24-27, 50; safety 104-108, 113
Aeronautics and Astronautics Coordinating Board (AACB), 43, 60
Aeronautics and Space Engineering Board 97-98
Aeromedical Evacuation Modernization Program 54
Aeronomy 73-74
Aerospace Research Pilots 44, 54
Aerothermodynamics 30
Advanced Manned Strategic Aircraft (AMSA) 54
Advanced Turbine Engine Gas Generator (ATEGG) 58
AGENA 23
Agency for International Development (AID) 82
Agriculture, Dept. of 22, 43
AH-56A (Cheyenne) 52; AH-1G (Huey Cobra) 52
Airborne Warning and Control System (AWACS) 59
Aircraft survivability 55
Air Force 83, 97; range support 61
Airglow 73-74
Alloys 23-24
ALOUETTE 48, 85
Ames Research Center 26, 28, 29, 33
Antarctica 75-76
Antenna (despun) 57
Antenna (210-ft.-dia.) 17, 38
APOLLO 1, 3, 4, 10-14, 60-61, 70, 81, 85, 96, 115-119
APOLLO Applications 14-15
APOLLO Lunar Surface Experiments Package (ALSEP) 18, 34, 65
APOLLO-SATURN 1, 10
APOLLO Telescope Mount 15, 31, 85
Applications Technology Satellites 4, 18, 20, 23, 77, 79, 83-84, 86, 114-115
ARCAS rocket 86
Argentina 40, 82
ARIEL 39
Arms Control and Disarmament Agency 121
Army 60
Army Map Service 60, 82
Asteroids 101
Astronauts 12; rescue and return treaty 2, 4, 69, 70; scientists as 95
ATLAS 23, 68; improved 23
Atomic Energy Commission (AEC) 35, 36, 42, 63
Attack aircraft 57
Australia 40, 82, 102
Automatic Picture Transmission (APT) 3, 5, 21, 78, 81, 84
Aviation, general 26

Baker-Nunn Camera 99, 102
Balloons 19, 30, 72, 102
Belgium 82
Benefits 3, 6-7
Bioastronautics 4, 95
BIOSATELLITE II 4, 10, 18, 20, 22, 115, 118-119
Blue Hill Observatory 74
Brazil 39

C5A 2, 4, 50
C-131A 59
Canada 39, 85
CENTAUR 22
Cerenkov radiation 102
Cerro Tololo Inter-American Observatory 72-73
CH-53A assault aircraft 53
Chad 40
Chemical propulsion 27-28
Chemical power 34, 35
Chile 73
Civil Aeronautics Board (CAB) 5, 105
CL-84 (tiltwing V/STOL) 53
Clear Air Turbulence (CAT) program 23, 54
Coast and Geodetic Survey 77, 82-84, 86
Coding 32

COIN aircraft 52
Comets 99, 101-102
Command and Service Module (CSM) 11-14
Commerce, Dept. of 22, 43, 77, 82, 90
Communications, Defense Satellite program 45
Communications Satellite Act of 1962 112
Communications Satellite Corp. 3-4, 21-22, 112
Communications satellites 4, 21
Cosmic rays 75, 101-102
COSMOS satellites 81
COSPAR 91, 94
Cost reduction 40
Crab Nebula 102

DART 67
Deep Space Network 37-38
Defense, Dept. of 44-62, 82, 85
DELTA 22
Diurnal variations 100

Earth resources satellites 3, 22, 82
Eastern Test Range 49, 61
Ecuador 40
Edwards AFB 97
Electronics and control 31-33
Electronics Research Center 31-32
Electrophysics 23
Environmental Data Service 77
Environmental Science Services Administration 77, 80, 83-84, 96, 105
ESRO satellite 39
ESSA satellites 5, 10, 18, 21, 77-78
European Launcher Development Org. (ELDO) 40, 122
European optical station 100
European Space Research Org. (ESRO) 70, 88, 118
EXPLORER 4, 19, 22, 85

F-12 54
F-106 24
F-111 series 2, 24, 50-51
Federal Aviation Administration 2, 25-26, 104-110
Federal Communications Commission 112-114
Finland 39
Fleet Ballistic Missile submarines 48
Fluid dynamics 23
Ford Foundation 73
France 100
Free molecular flow 75

Gamma-ray astronomy 102
Gas dynamics 75
GEMINI 22, 44, 117-120
General-purpose airborne simulator (GPAS) 26
GEOCEIVER 48
Geodesy 75, 99-100
Geodetic satellites 4, 21-22, 47
Geological Survey, U. S. 96
GEOS 21-22, 47, 86, 99-100
Germany 39, 82, 93-94
Global atmosphere research program 95
Goddard Space Flight Center 31, 88, 100
Gravity-gradient stabilization 57
Gravity, reduced 29
Greenland 101

Harvard University 73-74
Hawaii 99-100
Helicopter development 52
Helium 75, 100
HL-10 lifting body 30
Hungary 82
Hurlburt, E. O. Center for Space Research 73

Incentive contracting 40
India 39, 82
Infrared (forward-looking) 59
Initial Defense Communications Satellite Project (IDCSP) 46
Institute for Earth Sciences 82
Institute for Oceanography 86
Institute for Telecommunication Sciences and Aeronomy 85
INTELSAT consortium 70-71, 112, 118
INTELSAT satellites 3, 10, 99
International Astronomical Union 102
Interior, Dept. of 22, 43
International Civil Aviation Organization (ICAO) 114
International cooperation 5, 39
International Council of Scientific Unions (ICSU) 94
International Year of the Quiet Sun (IQSY) 75
Interplanetary Monitoring Platform (IMP) 19
Ionosphere 74-75, 85-86, 103

ISIS 85-86
Israel 82
Italy 22, 39

J-2 engine 61
Japan 39
Jet Propulsion Laboratory (JPL) 28, 34
Johnston Island 99
Jupiter 103

K-50 camera 99
Kennedy Space Center 11, 13
Kenya 22
Kitt National Observatory 72
KIWI (see Nuclear Rocket Programs)

Labor relations 41
Langley Research Center 26, 28-29, 33, 97
Lasers 5, 32, 59, 99-100
Launch vehicles 22-23, 61
Lewis Research Center 26, 30
Life detection 76
Life sciences 92
Life support 29
Lifting body re-entry vehicles 2
Light attack aircraft 51
Lightning 25
Load Alleviation and Mode Stabilization (LAMS) 58
Long-Distance Point-to-Point System 45
Los Alamos Scientific Laboratory 63, 74
Low-temperature research 89
LUNA 102
Lunar and planetary programs 15
LUNAR MODULE (LM) 12-14
LUNAR ORBITER 1, 4, 10, 23, 60, 103, 115, 117
Lunar support (Army) 60

M-2/F-2 lifting body 30
Magnetosphere 75
MANNED ORBITING LABORATORY (MOL) 2, 4, 44, 70, 116, 118
Manned Spacecraft Center 29
Manned Space Flight Network 37
Manned Space Flight Policy Board 60
MARINER 2, 4, 10, 16-17, 23
Mars 17-18, 103
Marshall Space Flight Center 13
Materials research 23-24, 88
Maui, Hawaii 100
Max Planck Institute 93
MERCURY 61, 103
Meteoritics 99, 101-102
Meteorological satellites 21, 78, 84
Meteorology 75
Mexico 40
Microwave radiation 102-103
Mississippi Test Facility 85
Moonwatch 99
Mount Hopkins, Ariz. 100, 102

NASA Communications Network (NASCOM) 38
National Academy of Engineering 91, 97
National Academy of Sciences 91, 93, 95
National Aeronautics and Space Act 6
National Aeronautics and Space Administration 10-43, 82-86, 88, 90, 93-96, 98, 120, 122
National Aeronautics and Space Council 6-9, 43, 98
National Bureau of Standards 31, 77, 83, 86-90
National Center for Atmospheric Research (NCAR) 73-74
National Environmental Satellite Center (NESC) 77, 82-84
National Geodetic Satellite Program 40
National Institutes of Health 29
National Meteorological Center 77-79
National Operational Meteorological Satellite System 78
National Radio Astronomy Observatory 72
National Range (DOD) 49
National Research Council 91
National Science Foundation 72-76, 91
NATO 82
Naval Research Laboratory 73
Navy, U. S. 22, 61, 82, 85, 89
Navigational satellites 3, 5, 48, 57, 82
NERVA 5, 36, 63
New Zealand 40
NIMBUS 21, 65, 79-80, 86
Noise alleviation 25
Nuclear detection 5, 47, 68
Nuclear Rocket Development Station 36
Nuclear rocket program 11, 35-36, 63
Nuclear space systems 11, 33-34, 63

OBSERVATORY satellites 4, 10, 18-19, 22-23, 31, 118

Office of Naval Research 97
Office of State Technical Services 77, 90
Optical satellite tracking 99-100
Orbital Workshop 15
Over the Horizon Detection (OHD) 55
OZONE 75

PAGEOS 4, 22, 48
PEGASUS 31
Philippines 40
PHOEBUS 5, 35-36
PIONEER 4, 19, 22, 32
Planetary atmospheres 73-74
Planetary studies 102-103
Plasmas 75
Plastics 24
Plutonium 238 67
Poland 82
Polonium 210 67
Power (space) 56, 65
Power conversion 66
Prairie Network 101
Princeton University 75
PRIME/PILOT 55
Puerto Rico 84

Radars 55, 102
Radio Attenuation Measurements (RAM), Project 32
Radio telescopes 72
Radioisotope 66
Respiratory research 29
Rocket astronomy 72
Runways 24-25

S-II SATURN stage 13
SAN MARCO 22, 39
Satellite Control Facility 49
Satellite Infrared Spectrometer 80
Satellite network 37
SATURN I (Uprated) 12-13, 62, 85
SATURN V 1, 3, 4, 10-14, 17, 61, 85, 116, 118-119
SCOUT 22
Senegal 40
SERT 35
Shed Light, Project 59
Smithsonian Institution 43
Smithsonian Astrophysical Observatory 99-103
SNAP systems 5, 21, 33-34, 65
Solar cells 55
Solar flares 102
Solar power 34
Solar radiation monitoring program 57
Solar research 73-74
Solar wind 73-74, 101
Solid rockets: 156-in. 56; 260-in. 5, 10, 27
Sounding rockets 5, 19, 21
South Africa 40
SOYUZ 3
Space nuclear safety 67
Space planning objectives 7
Space Science Board 91, 95, 97
Space suits 29
Space vehicle systems 30-31
Spacecraft oceanography 120
Spain 99
SPASUR 50
Standard Earth (geodetic model) 100
START 55
State, Dept. of 69-71
Sun 18-19
Supersonic Transport (SST) 2, 4, 10, 26, 52, 97, 107, 109, 111
Surinam 40
SURVEYOR 1, 2, 4, 10, 15-16, 22, 60, 102, 115, 117-119
Switzerland 39
SYNCOM 45-46, 119

Tech Briefs 42
Technology utilization 41
Telecommunications services 85-86
Thermionic power generator 66
Thesaurus 42
THOR-DELTA 22
TIROS 21, 78-79, 84
TIROS Operational Satellite System (TOSS) 81, 85
TITAN IIIC 4, 45, 68
TITAN IIIM 2, 44
Tokyo Astronomical Observatory 99
Total In-Flight Simulator (TIFS) 59
Tracking and data acquisition 37-38, 71
TRANSIT (see navigational satellites)
Transportation, Dept. of 104-111
Tsunami warning system 83

United Kingdom 39-40, 57, 82
United Nations 2, 69, 121-122
United Nations Conference on Outer Space 69

United Nations Space Treaty 2, 4, 69, 118, 121; agreement on astronaut rescue and return 4-5, 69
United States Information Agency 115-120
United States Patent Office 77
University of California 75
University of Chile 73
University of Riga 99
University programs 38
USSR 3, 8, 81, 99

Vandenberg AFB 2
VELA 5, 47, 68
VENERA 4 2, 3, 103
Venus 2, 4, 10, 16-17, 74, 103
Vice President 6
VOYAGER 17-18
V/STOL 10, 26, 53, 57
VTOL Integrated Flight Control (VIFC) 58

Wallops Island 85
Water (lunar) 102-103
Weather Bureau 3, 77, 79, 84-85
Western Europe Satellite Tracking network 99-100
Western Test Range 49, 61
World Data Centers 94
World Magnetic Survey Project 84
World Meteorological Organization (WMO) 82
World Weather Watch 79

X-15 2, 4, 10, 24, 27, 53
X-22 53
X-24A 55
XB-70 10, 26, 50, 52
XV-4A 58

YF-12A 54

GSA DC 68-9417